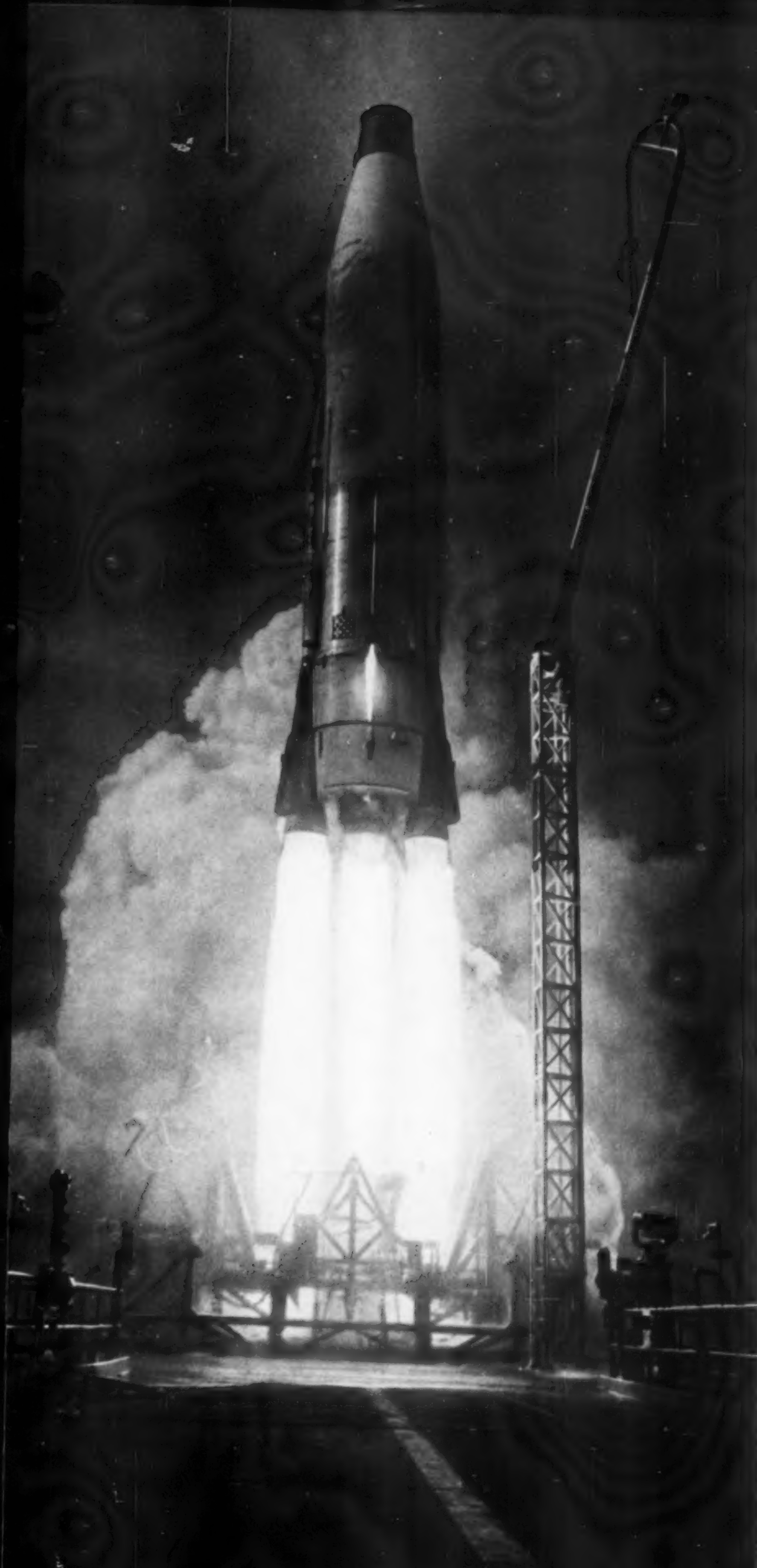


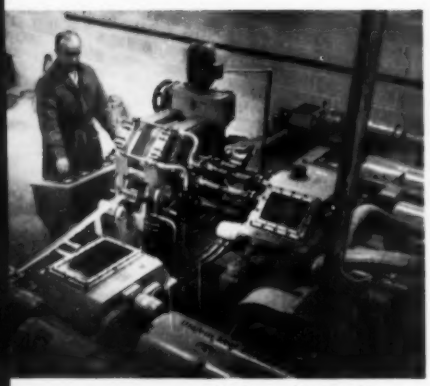
Metal Progress

NOVEMBER 1959

Custom conversion

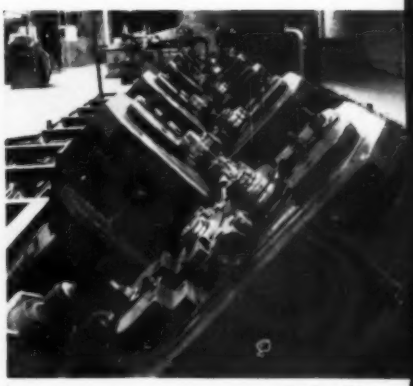
Announcing...

NEW SPECIALIZED FACILITIES FOR PROCESSING REACTIVE AND REFRACTORY METALS



Strip and foil rolling

Wire drawing



Rod rolling

In custom conversion of special metals and as a supplier of specialty wire, Johnston & Funk has already built an outstanding reputation. Flexibility, fast service on special orders, and exacting quality control have been the basis for this success.

Now, we are pleased to announce new and expanded facilities. J & F's ultra modern plant at Huntsville, Alabama, (shown below) offers the most up-to-date facilities for strip and foil rolling and special conversion work . . . in titanium, zirconium, tantalum, molybdenum, tungsten and specialty alloys.

These integrated, modern facilities can serve your needs for processing special metals in any form . . . from ingots to strip, foil, or wire. We can assist you with research, experimental or custom conversion projects. Write us for specific information, or ask for a copy of our *Facilities Brochure.*

J & F

Johnston & Funk

METALLURGICAL CORPORATION

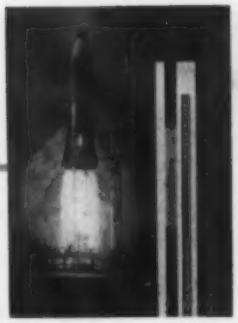
HUNTSVILLE, ALABAMA

An affiliate of P. R. Mallory Co. and Mallory-Sharon Metals Corp.

J & F headquarters and plant, Huntsville, Ala.

Metal Progress

November 1959 . . . Volume 76, No. 5



Cover shows test launching of the Atlas – America's first intercontinental ballistic missile. Photo provided by Convair-Astronautics Div., General Dynamics Corp. to highlight the lead article on p. 65.

Producing for the Supersonic Age

Engineering Articles

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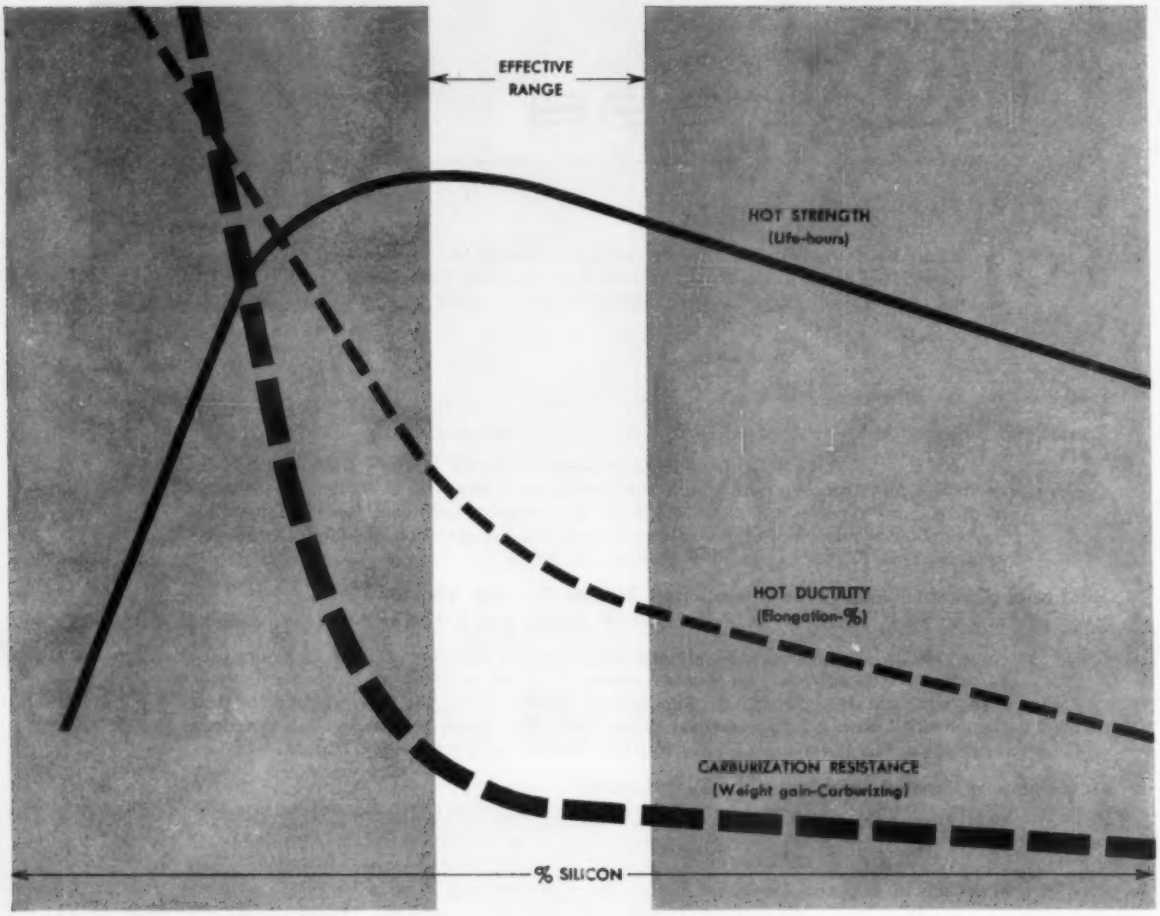
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



How to use

SILICON-CONTENT

to lengthen the life of heat-resistant castings

Silicon content can be used to give heat-resistant alloy castings higher hot strength, higher hot ductility and higher carburization resistance.

But these property refinements are possible only within the relatively narrow *effective range* of silicon content shown on the graph. Silicon content lower than the effective range would result in a higher rate of carburization and low hot strength. Conversely, silicon content above the effective range, while it provides excellent carburization resistance, produces low hot strength and poor hot ductility.

The effective range of silicon content varies with operating conditions. Electro-Alloys' metallurgical research has defined a number of ranges to deal with these varying conditions.

To insure proper silicon content and the accurate balance of all alloying elements, consult us at the initial stages of product development. Electro-Alloys Division, 1018 Taylor Street, Elyria, Ohio.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

Metal Progress

Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices Metals Park, Novelty, Ohio. Entered as second class matter at the Post Office in Mt. Morris, Ill. Vol. 76, No. 5, November 1959.

Press Breaks...

ACCORDING TO READERSHIP REPORTS, our Metals Engineering Digest Section (located in the back of the book with the fractional advertising) is read as much, if not more, than the main editorial section. This is a well-deserved compliment to the eminent metallurgists and engineers who devote much time and effort to preparing these digests for us.

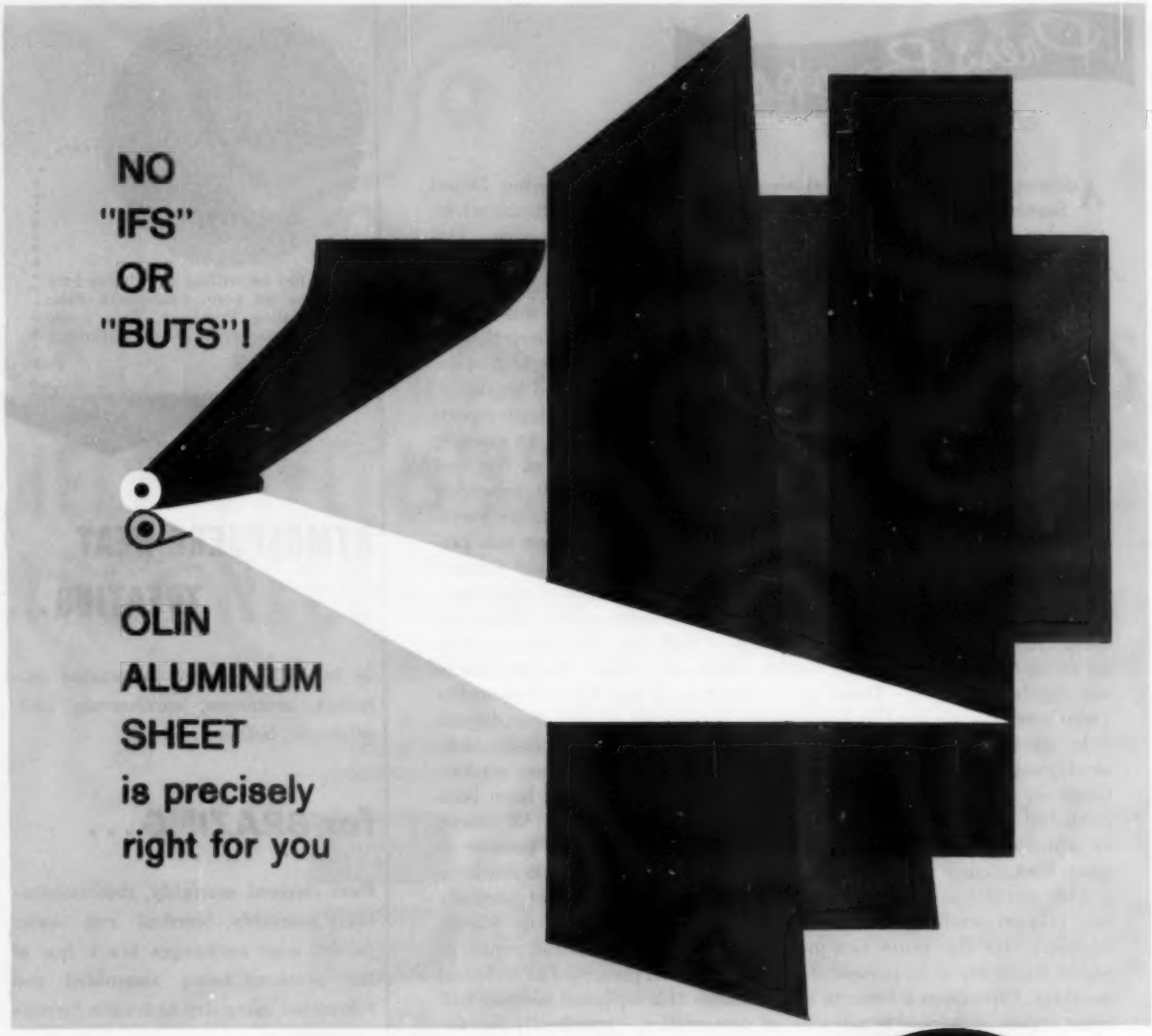
Yet, they are only links in a chain. There are many other steps which must be taken before this section is ready for you to read. Since there is room for only 10 to 15 digests a month, we must first decide which of the thousand or so articles published every month is to be selected for digesting. Also to be culled are numerous convention papers and many reports of limited circulation which ASM'ers would not usually see. An example is the lead digest on p. 140 of this issue (in editorial jargon, the lead digest is the one that starts off the section and generally is somewhat longer than the other digests) which tells of "Progress in Explosive Forming". As you will note from the initials at the end, this digest was prepared by Assistant Editor Ralph Dermott from a progress report (almost as big as the Cleveland Telephone Directory) on high-energy-rate forming by Lockheed Aircraft Corp. based on work under an Air Force contract. All of the editors on *Metal Progress* staff from the editor-in-chief on down occasionally prepare digests which supplement the services of our regular digesters. These go to Assistant Editor Carl Weymueller (who is responsible for this department) along with all the other digests.

In between other extensive editorial work, Carl looks over many technical journals seeking information which is important to our readers. Generally he settles on articles which most probably would have been published in *Metal Progress* had they been submitted to us. (Of course, an editor realizes that he can't publish all the good articles because of space limitations.) His main coverage is on journals which do not have a wide circulation and that you readers therefore would not normally see. (Consequently, you can expect to see many digests from foreign sources.) He also works to a great extent with preprints and copies of papers which are to be presented or have just been presented at technical meetings. Oftentimes a letter to the chairman of a technical meeting will bring copies of papers in advance of presentation – specifically for the digest department. This enables us to bring you information you may be needing on some particular job as soon as possible. Essential in assigning articles for digesting is our extensive card file which contains names of some 50 or so technical men who are well versed in one or more special fields. This file is referred to for qualified digesters.

Our consulting editors also assist in the digest department. For example, Arthur Tesmen speaks, reads and understands Russian with the same ease as you or I understand English. In the January International issue, you will see several digests of Russian articles prepared by him.

While we are talking about the back-of-the-book editorial section, we would like to call your attention to "Behind the Bylines", initiated in the September issue. If you will recall the September issue, and also refer to p. 213 in this issue, you will see that we are passing on some interesting information about the authorities who write for *Metal Progress*. Elizabeth McCall Aldrich, who handles many of the mechanical details of getting *Metal Progress* printed each month, is in charge of this new feature. If you catch her between operations on galleys with a paste pot and scissors, she explains that the objective of "Behind the Bylines" is to give our readers a closer look at the able men who appear in bylines on *Metal Progress* articles – not only a look at their technical qualifications but a side glance at their other interests and activities. We think this helps readers feel that the author is not only a name but a definite personality with his own likes and dislikes.

THE EDITORS



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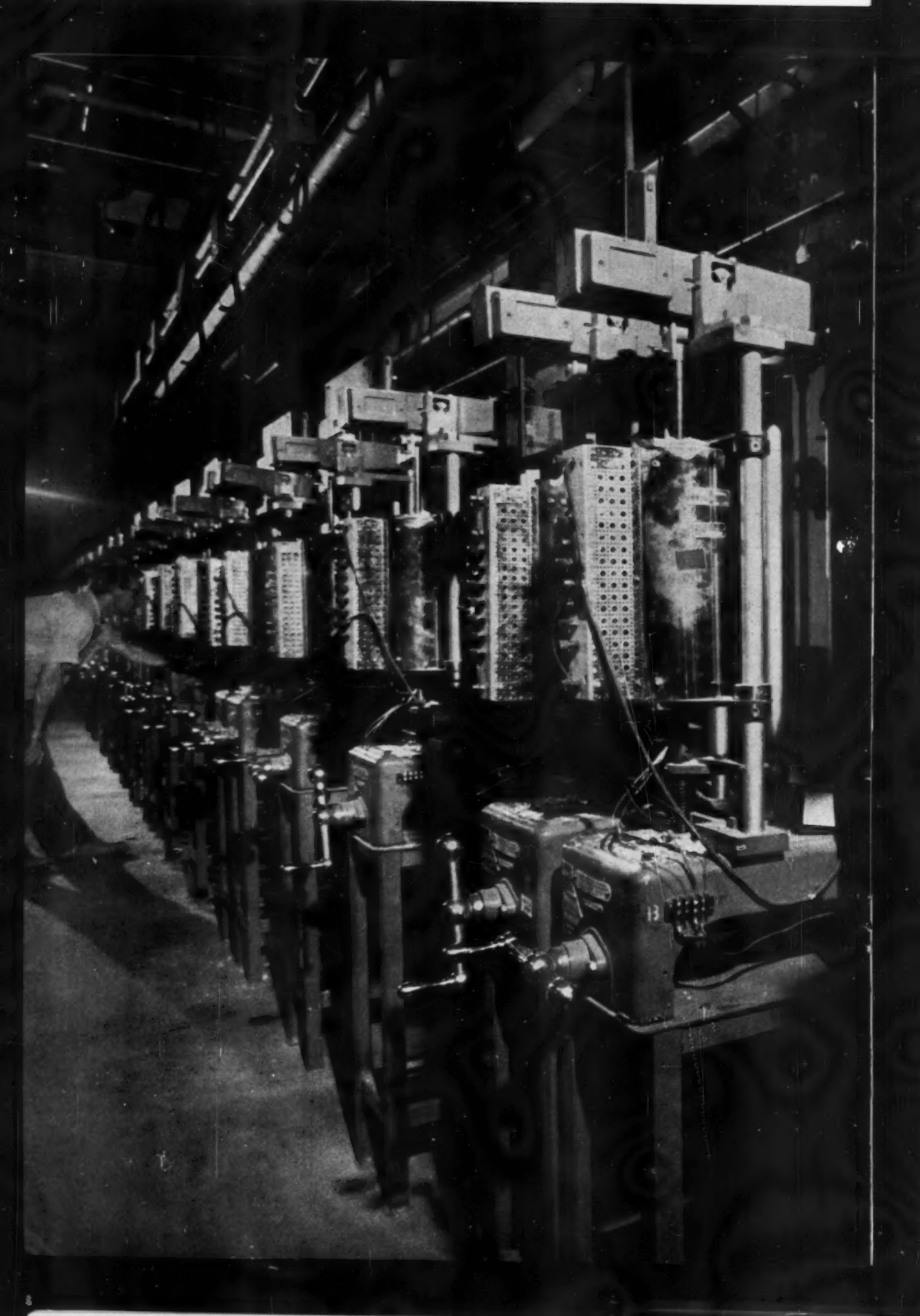
READERSHIP Eastmans RESEARCH

Metal Progress is available on microfilm from University Microfilms, Ann Arbor, Mich.



Every heat of every alloy proved on the spot

Stress-rupture testing at the Metals Division determines vacuum-induction-melted alloy life

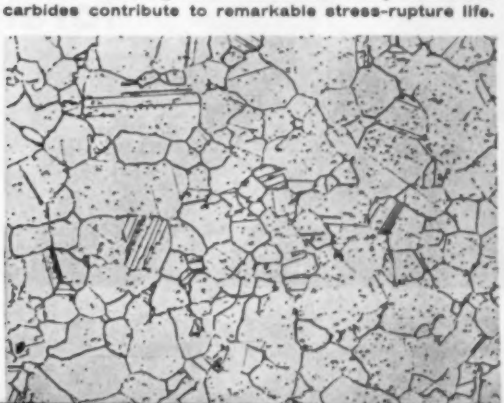
After vacuum induction melting, every heat of every alloy produced at the Metals Division, Kelsey-Hayes Company, undergoes complete testing. Included in this evaluation is the all-important stress-rupture life test.

In a massive laboratory at Metals Division, over 100 mechanical property testing machines find the rupture point of alloys under given conditions of stress, time and temperature. For example, UDIMET 700, one of the latest alloy developments at Metals Division, has a stress-rupture life of 60 hours at 1800° F and 18,000 psi. UDIMET 500 and 41, Waspaloy, M-252 and many alloys are produced and similarly evaluated at the Metals Division.

Your superalloy requirements can benefit from Metals Division vacuum induction melting facilities and technical experience. Write Dept. 11, Metals Division, Kelsey-Hayes Company, New Hartford, N. Y., for full details.

METALS DIVISION
KELSEY-HAYES COMPANY
NEW HARTFORD, NEW YORK

Over 100 stress testing machines (left) test high temperature properties of every alloy heat at Metals Division. Uniform grain structure and evenly distributed carbides contribute to remarkable stress-rupture life.



A DEVELOPMENT OF DIVERSEY RESEARCH

Diversey's new electrocleaning development can boost your output ...and reduce costs

This could be the electrocleaning improvement you've been waiting for. The combination of Diversey No. 15 SOAK CLEANER plus new Diversey No. 35 ELECTROCLEANER means increased production . . . and lower cost per part. You get absolute cleanliness with smut-free, waterbreak-free surfaces. The treatment results in more adherent plate . . . sharply reduced rejects . . . lower costs.

Here's the combination that is getting a new high in results on high-speed production lines:

Diversey No. 15 heavy duty soak cleaner. High speed removal of oily contamination • thorough emulsification • exceptional wetting action.

Diversey No. 35 high conductivity electrocleaner. Maximum conductivity . . . permits full loading of racks • produces waterbreak-free, smut-free surfaces, even in low current density areas.

Maintenance savings, too. Both cleaners deliver a new high in contamination tolerance for long solution life. And their advanced type water softening properties prevent hard precipitates from forming on tanks, reducing maintenance and down-time.

Get the facts now on the new cleaning combination that can give you better plating at less cost. See your Diversey D-Man or write Metal Industries Department, The Diversey Corporation, 1820 Roscoe Street, Chicago 13, Illinois.

DIVERSEY.

NOW GLOBAR® ELEMENTS ON LINE VOLTAGES... *ELECTRIC FURNACE HEAT*

GROBET FILE CO. OF AMERICA, INC., uses 3 across the line electric furnaces for clean, uniform heat treatment of chisel cut and rotary files. Operation is critical as cutting edges must be protected during hardening. Equipment consists of 3 Model Y furnaces with the Sentry Diamond Block method of atmospheric control, manufactured by the Sentry Company, Foxboro, Mass. These and all other Sentry furnaces use GLOBAR elements "across-the-line", exclusively.

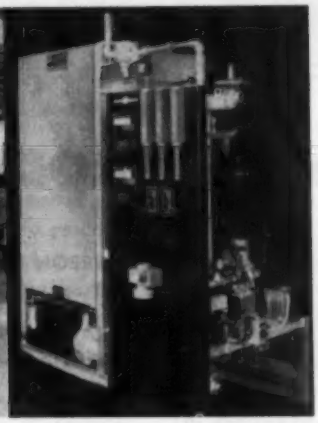
OPERATE CUT COSTS OF *TREATMENT*

Medium temperature application of silicon carbide elements "across-the-line" eliminates transformers—simplifies furnace installations

Compact, simply controlled electric furnaces, connected "across-the-line" on 115 or 230-volt power distribution systems, offer new opportunities for economical heat treatment under favorable conditions in the medium temperature range. Higher temperatures are possible for certain operations.

Long-life GLOBAR Delta elements that increase in resistance at a slow, uniform rate make on-the-line operation of these elements practical and economical. Equipment cost is kept low because tap transformer control is not required.

WIRE ANNEALING FURNACES at Electric Wire Company of Northampton, Mass., use GLOBAR elements across a 220 volt line and operate at 1800° to 2250° F. GLOBAR silicon carbide elements installed over 18 months ago are still in use.



LATEST TYPE "IGL" Hayes Protective Atmosphere Generator, uses 12 GLOBAR Delta elements on 230-volt supply. Customers report only slight increase in resistance after extended service.

New advance increases ECONOMIC ADVANTAGES OF ELECTRIC HEAT

Electric heating is meeting the growing demand of industry today. The adaptability, versatility and dependability of long-life silicon carbide elements, the ease of replacement without a complete shutdown, and minimum maintenance are vitally important to the operator.

Electric heating is economically attractive for a wide range of processing operations. Simple, low-cost installations, without expensive transformers, are easily controlled by an automatic pyrometer and magnetic contactor up to 2000° F, and favorable operating requirements may permit higher temperatures. Applications should be carefully evaluated and individually engineered. Electric heating efficiency is high, you don't pay for Btu's that go up the stack. Exhaust and fuel storage facilities are unnecessary. It is clean, safe and quiet with no fire or explosion hazard. Compact GLOBAR equipped furnaces may be located anywhere in a production line. Product quality is improved and rejects are reduced.

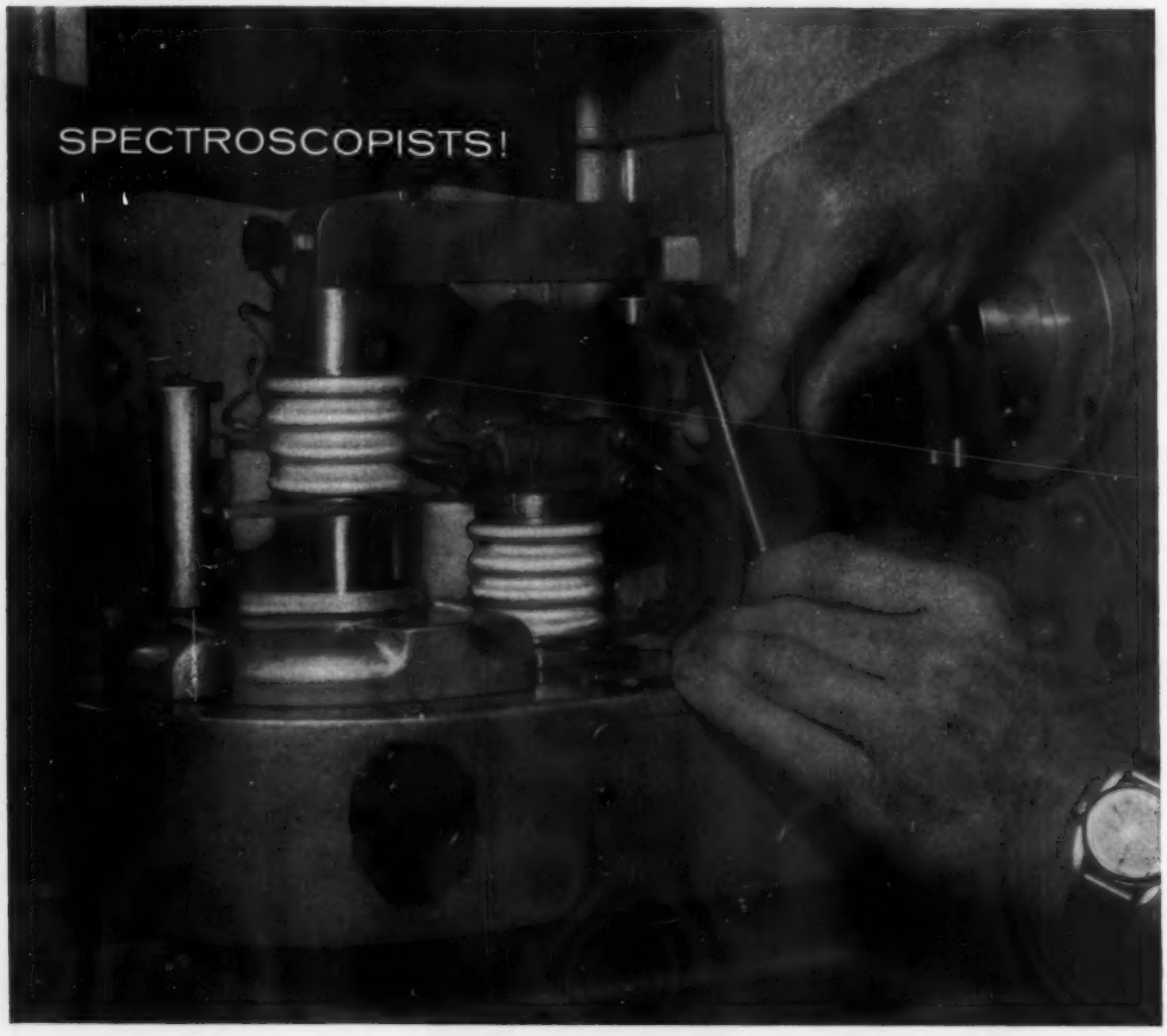
Consideration of all factors usually shows savings that may not be apparent in a simple comparison of fuel costs.

Typical applications for GLOBAR Delta elements include Ceramic firing, heat treatment, forging, sintering, brazing, annealing, melting, assaying, roasting and laboratory control and testing.

Find out how your operation can profit by using GLOBAR Delta silicon carbide heating elements. Your furnace builder can supply you with full details. The Carborundum Company, Refractories Division, Globar Plant, Dept. MP119, Niagara Falls, New York.

CARBORUNDUM

Registered Trade Mark



Take advantage of a complete line of

NATIONAL ELECTRODES and POWDERS

TRADE-MARK

Whatever technique you use... whether you are doing quantity runs or special individual tests... there is a "National" spectroscopic product to assure accurate results every time.

NEW GRAPHITE GRADE SPK—offers superior *reproducibility*. A free sample of this high-purity rod will prove this on your tests. Also available in preforms.

GRAPHITE GRADE AGKSP—the accepted industry standard in high-purity electrodes. Available in rods and preforms.

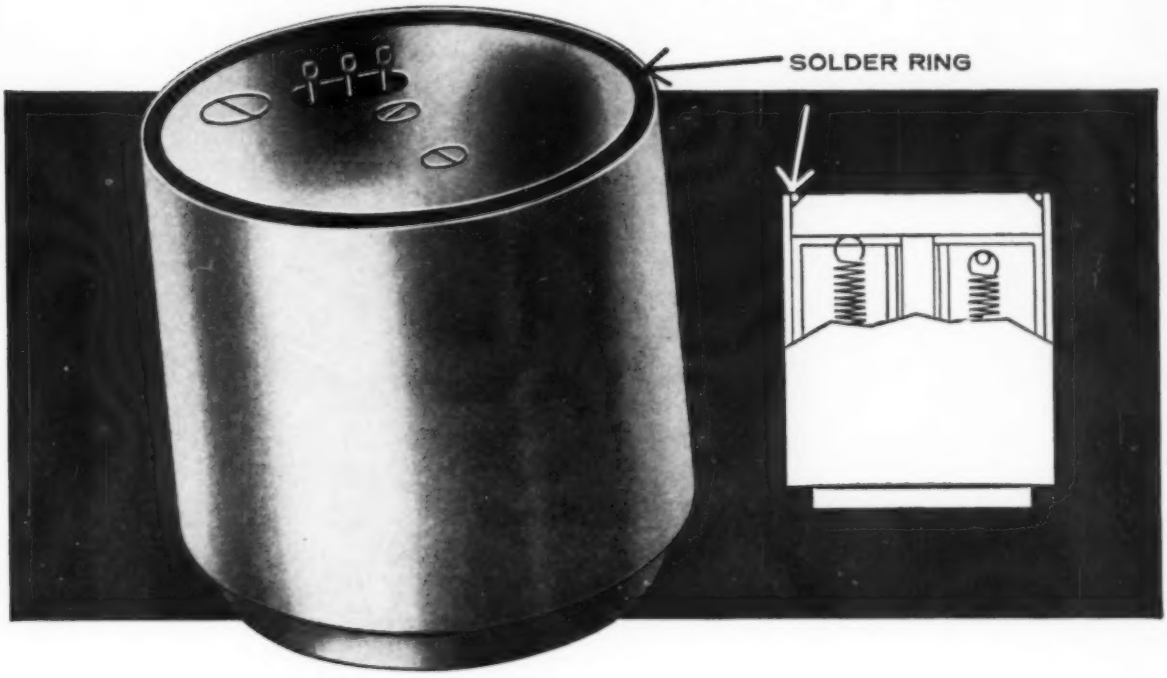
CARBON GRADE L113SP—a high-purity carbon rod for specialized applications.

GRAPHITE POWDERS SP1 AND SP2—used as a diluent and for pellet forming.

These products are manufactured from raw material to finished product in NATIONAL CARBON plants. Exclusive purification methods provide a uniform product from end to end and shipment to shipment. Use "National" spectroscopic products on all your analyses.

Precision soldering 7 Times Faster...

with TOCCO* *Induction Heating*



When G. M. Giannini and Co., Inc., Pasadena, California, switched from old-fashioned methods to TOCCO Induction Heating they increased production of these high-precision accelerometers from 4 to 30 per hour—with a commensurate *decrease* in production costs.

Here's what a Giannini official has to say about the TOCCO installation: "Prior to using TOCCO for this purpose, we had tried soldering irons, normal torches, resistance sealing, and even threaded screw fittings, with uniformly poor results. Essentially, the TOCCO unit has permitted us to build, in production quantities, oil-filled hermetically sealed units that could not be produced in any other way."

Whether your production bottleneck involves soldering, brazing, heat treating or heating for forming it pays you to investigate TOCCO as an economical way to do it better, faster and at lower cost.

TOCCO

JUST PUSH A BUTTON

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Please send copy of "Typical Results of TOCCO Induction Brazing and Soldering".

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Company_____

Address_____

City_____ **Zone**____ **State**_____

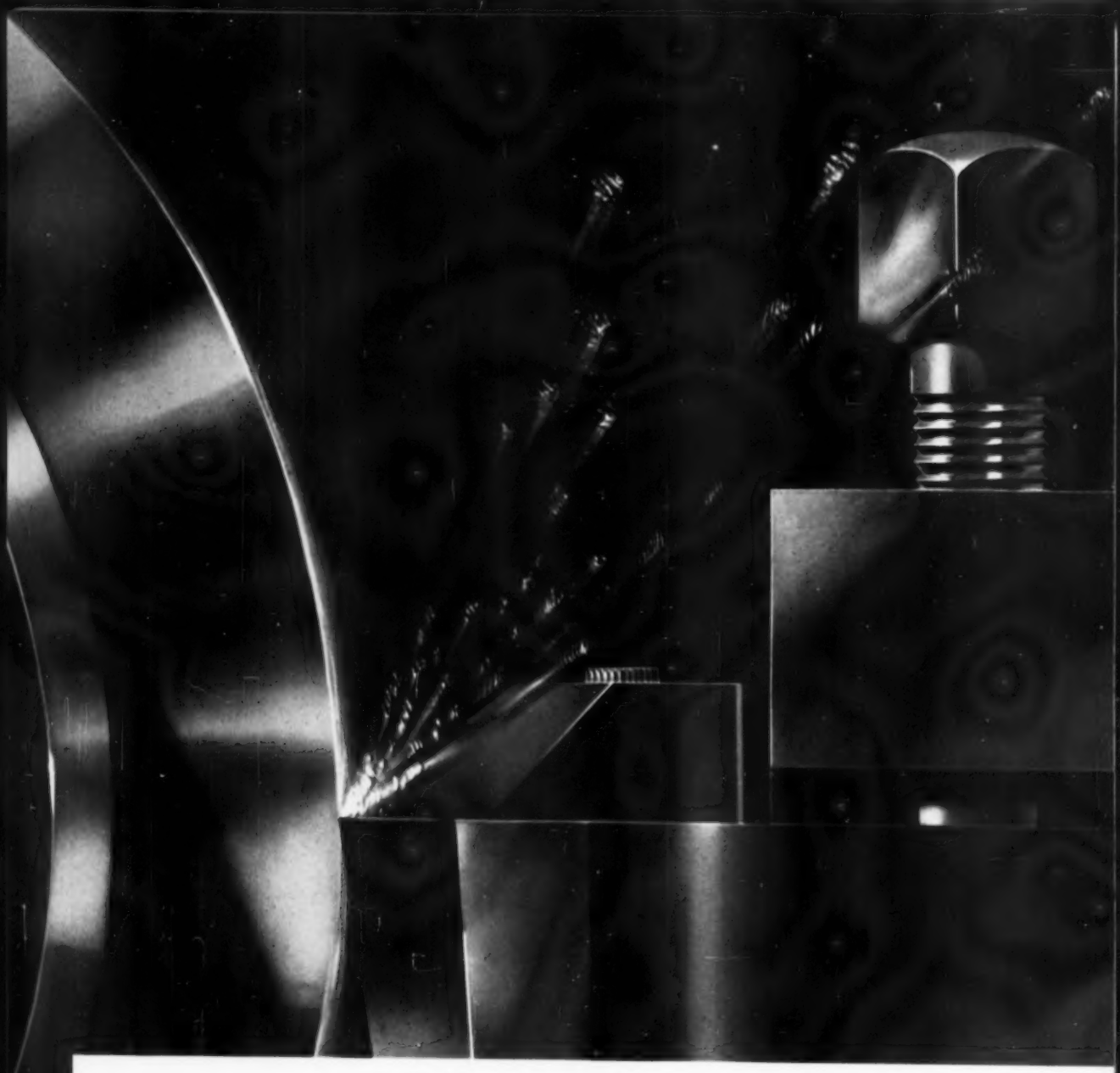


Illustration of Malleable casting being turned at 1,400 surface feet per minute with a 0.100" depth of cut using an oxide tool.

Machinability is Malleable

It's the finished cost of machined components that's important to you. Remember then . . . Malleable iron is more machinable than any other ferrous metal of similar properties. With Malleable castings you'll reduce machining time as much as 50% . . . increase tool life up to 250% . . . get unexcelled surface finishes . . . and end your reject problems.

To find out how much you can cut your costs and improve your profits, contact one of the progressive firms that displays this symbol—

MEMBER
MALLEABLE
CASTINGS COUNCIL

If you wish, you may inquire direct to the Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio, for information.

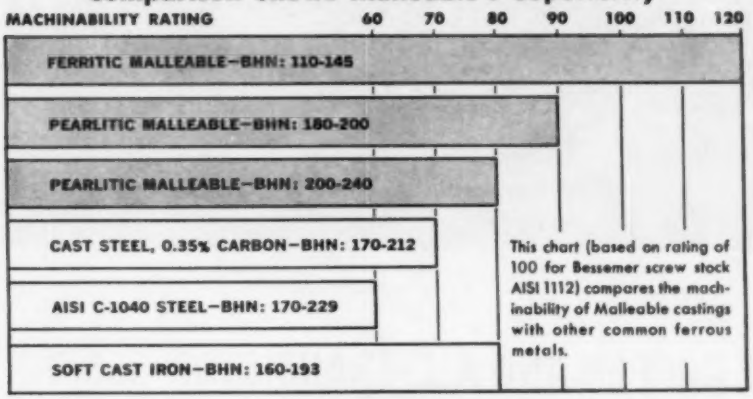
Machining Malleable Castings—Important Key to Cost Reduction

Malleable castings—the most machinable of all ferrous metals—cut quality components costs

Production men know that machining time, power consumption and rejects drop with the use of Malleable iron castings, while tool life and profits shoot up. The reason is simple: Malleable iron is the most machinable of all ferrous metals of similar properties.

The following important factors work together to give Malleable such machining superiority: Malleable's microstructure contains tiny, evenly distributed nodules of carbon that help cutting tools quickly break the removed metal into small (Class A) chips; the carbon also acts as a lubricant, prolonging tool life; uniformity of properties throughout every casting permits running at optimum machining conditions.

Comparison Shows Malleable's Superiority



Typical Example Shows Savings of 70% to 250%

The conversion of automotive universal joint yokes from steel forgings to pearlitic Malleable castings typifies the savings provided by Malleable castings. Costs for the rough pieces and performance characteristics of the two materials are comparable. However, the castings are much more economical to machine. Considering that machining often costs two to four times as much as the rough parts, the economy resulting from using Malleable castings is substantial.

Conversion of this universal joint yoke to a Malleable casting increased production, lowered direct and tool room labor, and cut tool replacement.

One volume user of Malleable joint yokes reports the following savings after changing from steel to Malleable castings: 70% longer tool life in broaching the splines; 250% more pieces cut by the nut seat cutters; 149% more pieces in turning and facing the hub; an increase of 100% in production between wheel dressings in grinding the hub; 246% greater production in drilling the cross holes.

In each of these operations, the change to Malleable castings cuts direct production time by reducing the frequency of tool changes. Tool room labor and tool replacement are both reduced to fractions of their previous costs.

Throughout the metalworking industry, part after part is now being initially designed of Malleable or converted from other materials to take advantage of Malleable's unrivalled machinability . . . to produce better parts at lower costs.

New Information Now Available on Machining Malleable

Data Unit 106—Machinability of Malleable Castings—can be obtained from any member of the Malleable Castings Council, or from the Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

These companies are members of the

MALLEABLE CASTINGS COUNCIL

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Connecticut Mall. Castings Co., New Haven 6
Eastern Malleable Iron Co., Naugatuck
New Haven Malleable Iron Co., New Haven 4

DELAWARE
Eastern Malleable Iron Co., Wilmington 99

ILLINOIS
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Chicago Malleable Castings Co., Chicago 43
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Link-Belt Company, Indianapolis 6
Muncie Malleable Foundry Co., Muncie
National Mall. & Steel Castings Co., Indianapolis 22
Terre Haute Mall. & Mfg. Corp., Terre Haute

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW JERSEY
Meeker Foundry Company, Newark 4

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Canton Malleable Iron Co., Canton 5
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
Maumee Malleable Castings Co., Toledo 5
National Mall. and Steel Castings Co., Cleveland 6

PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

WEST VIRGINIA
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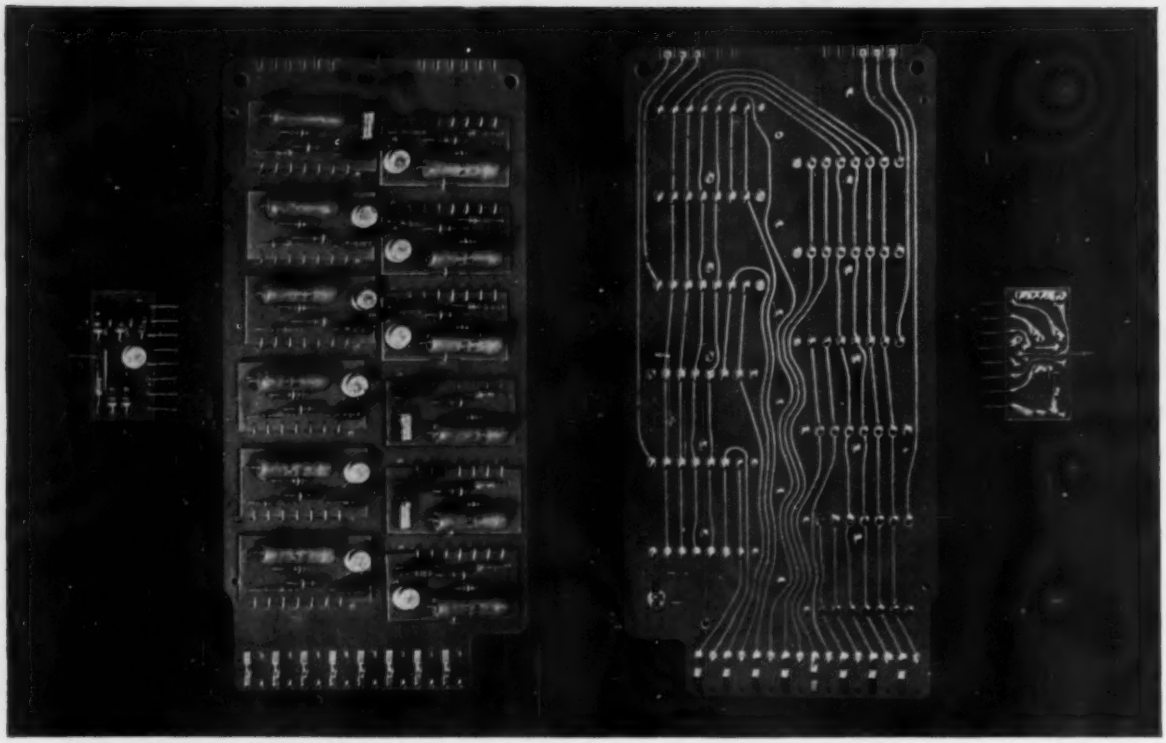
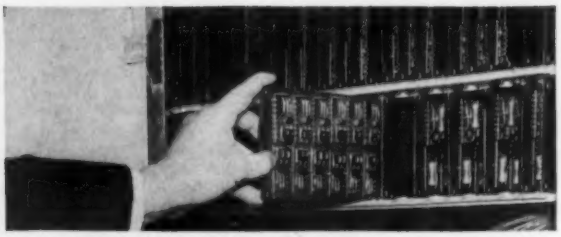
Milwaukee Malleable & Grey Iron Works, Milwaukee 46



In the electronic logic elements of the RCA "501" data processing system, transistors and other small components are mounted on plastic wafers with printed-circuit wiring (small units right and left, above). The wafers, in turn, are mounted on thin plastic boards, also with printed circuits (center, above). This modular construction reduces size of the system by 75%, increases reliability, reduces maintenance.

PRINTED CIRCUITS OF COPPER AND ALL-TRANSISTOR DESIGN HELP MAKE 75% SIZE REDUCTION IN RCA DATA PROCESSOR



Modularized circuit elements are installed in the system by sliding them in place. Contacts on outside edge make possible quick checkout and testing without removing boards. Many thousands are used in each system.

The "501" is designed to handle paper work—bills, reports, payrolls, etc.—accurately, economically, and at extremely high speed. It serves businesses ranging from banks and utilities to steel mills.

With the growing importance of miniaturization and reliability in electronics and nucleonics, Anaconda electrical copper products take new and varied forms—find new and more sophisticated uses.

In the compact new all-transistor data processing system shown above, the printed circuits are etched from Anaconda "Electro-Sheet" copper foil. This is electrodeposited paper-thin copper with quality carefully controlled to meet NEMA specifications. Bright on one side, it has a matte finish on the other for a firm bond to the circuit board. "Electro-Sheet" is furnished in various thicknesses to exceptionally close tolerances.

In other fields, the growing need for compact electrical assemblies which can handle high current densities calls for hollow copper conductors for fluid cooling. And for new environmental conditions, more difficult application needs, there are new copper alloys.

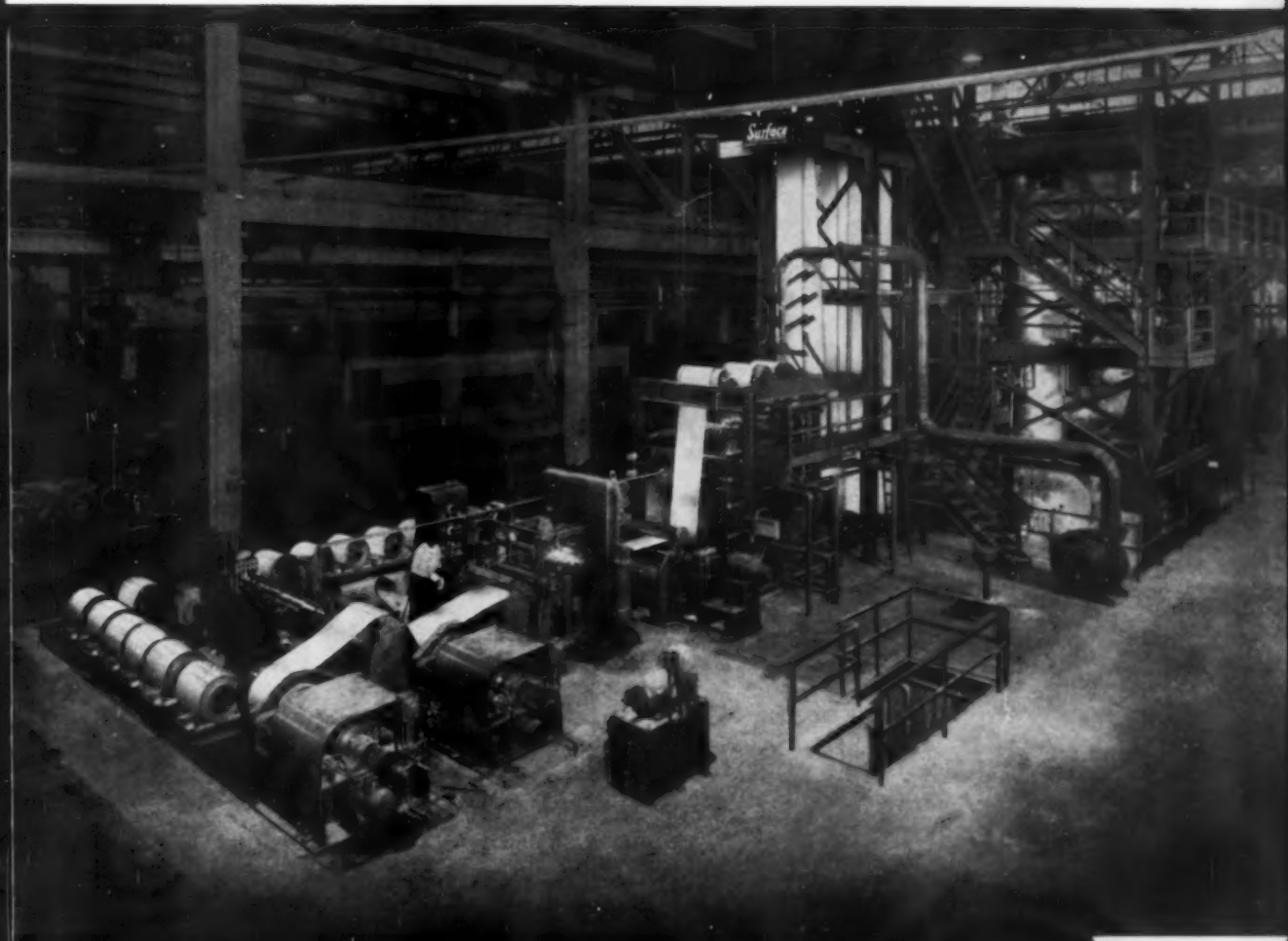
METALLURGICAL ASSISTANCE. Whatever your problem in electrical conductors, Anaconda metallurgical specialists will gladly help you select the metal—and the form or shape—best suited to your needs. See your American Brass representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

5946

ANACONDA®

ELECTRICAL COPPER PRODUCTS

Made by The American Brass Company



SURFACE POWER CONVECTION
achieves uniform grain size at unprecedented speeds

This Surface line is designed to continuously heat brass strip at speeds up to 200 feet per minute.

But unprecedented process speed is not the only profit which can be credited to Surface Power Convection, which heats the strip. Equally important are uniform control of grain size from edge to edge, and improved surface quality.

The key to such high-speed high-quality production is the tremendous wind velocity achieved by Surface Power Convection. In this furnace, wind speeds reach 136 miles per hour—a velocity unheard-of in convection furnaces up to now.

And the best news about Surface Power Convection is that it can be applied to virtually any type of heat treating equipment you can think of—batch or continuous, direct or indirect fired, straight air or atmosphere.

You know how higher speeds and better quality could improve your profits. Surface Power Convection will give you both. Write for Bulletin SC-182.

SURFACE COMBUSTION CORPORATION · 2377 Dorr Street, Toledo 1, Ohio

In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario

wherever heat is used in industry

Surface

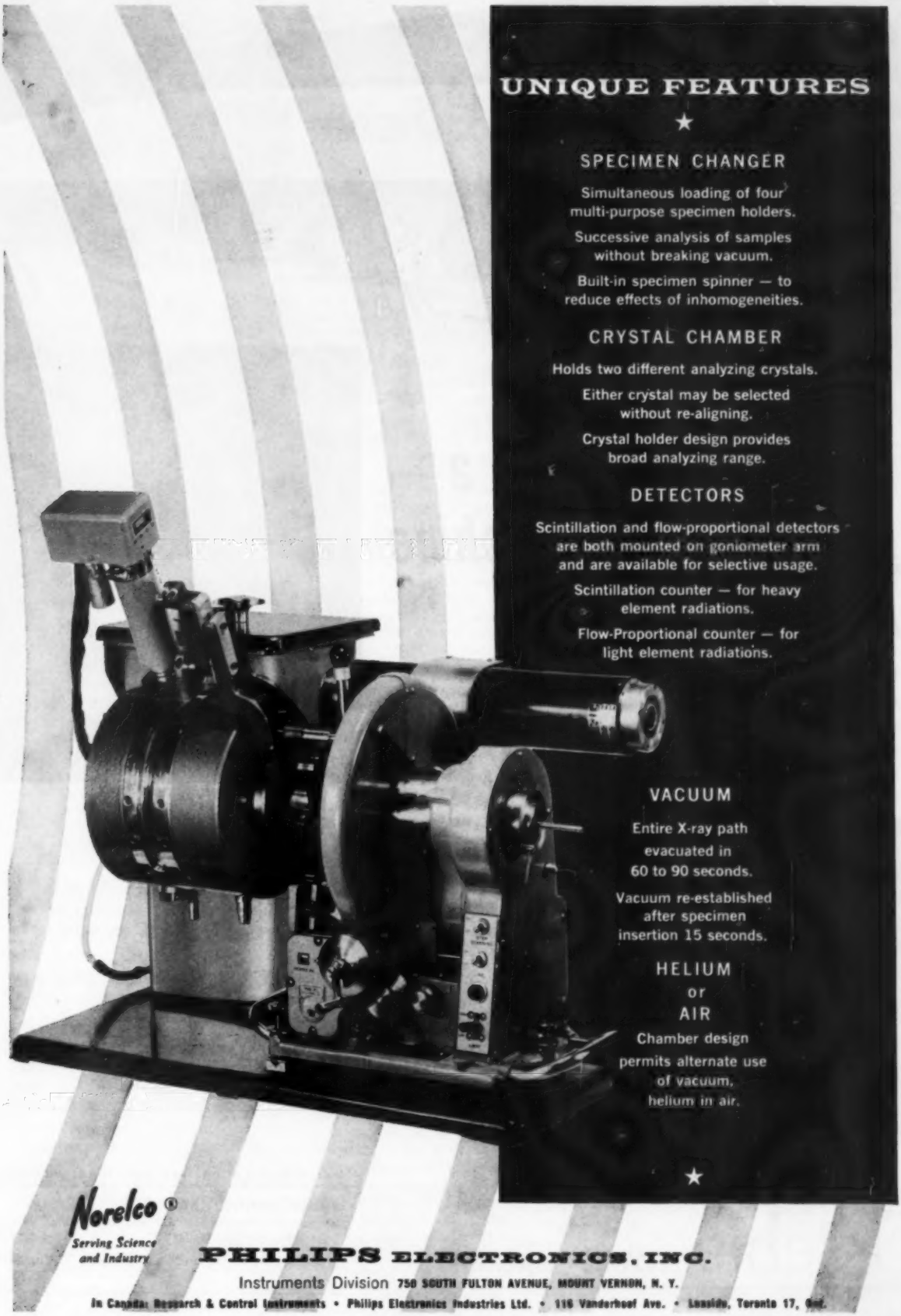
NORELCO ANNOUNCES

THE NEW UNIVERSAL VACUUM X-RAY SPECTROGRAPH

For Element Analysis in VACUUM HELIUM OR AIR

The FIRST and ONLY WIDE RANGE UNIVERSAL X-RAY SPECTROGRAPH

X-ray Spectrographic Analysis has long been recognized as a vital, non-destructive method of rapid element determination. The range of elements amenable to X-ray analysis has grown steadily with the years. Special techniques and equipment have been devised, particularly for lighter elements in the range of sulphur (16) through magnesium (12). The helium bag used on various types of standard Norelco spectrographic equipment is a familiar sight in laboratories throughout the United States and The World — yet — despite technological advances, cost considerations as well as commercial scarcity of helium gas have retarded adoption of gas atmosphere techniques. The recent development after intensive research and field testing, of the new Norelco Vacuum X-ray Spectrograph, has eliminated this obstacle and will now meet the increasing demand for wider application of X-ray spectrography in light element determinations. In fact, appreciably higher intensities for the elements number 17-30 may now be realized over previous spectrographic procedures.



UNIQUE FEATURES

★

SPECIMEN CHANGER

Simultaneous loading of four multi-purpose specimen holders.

Successive analysis of samples without breaking vacuum.

Built-in specimen spinner — to reduce effects of inhomogeneities.

CRYSTAL CHAMBER

Holds two different analyzing crystals.

Either crystal may be selected without re-aligning.

Crystal holder design provides broad analyzing range.

DETECTORS

Scintillation and flow-proportional detectors are both mounted on goniometer arm and are available for selective usage.

Scintillation counter — for heavy element radiations.

Flow-Proportional counter — for light element radiations.

VACUUM

Entire X-ray path evacuated in 60 to 90 seconds.

Vacuum re-established after specimen insertion 15 seconds.

HELIUM or AIR

Chamber design permits alternate use of vacuum, helium in air.

★

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Serving Science and Industry

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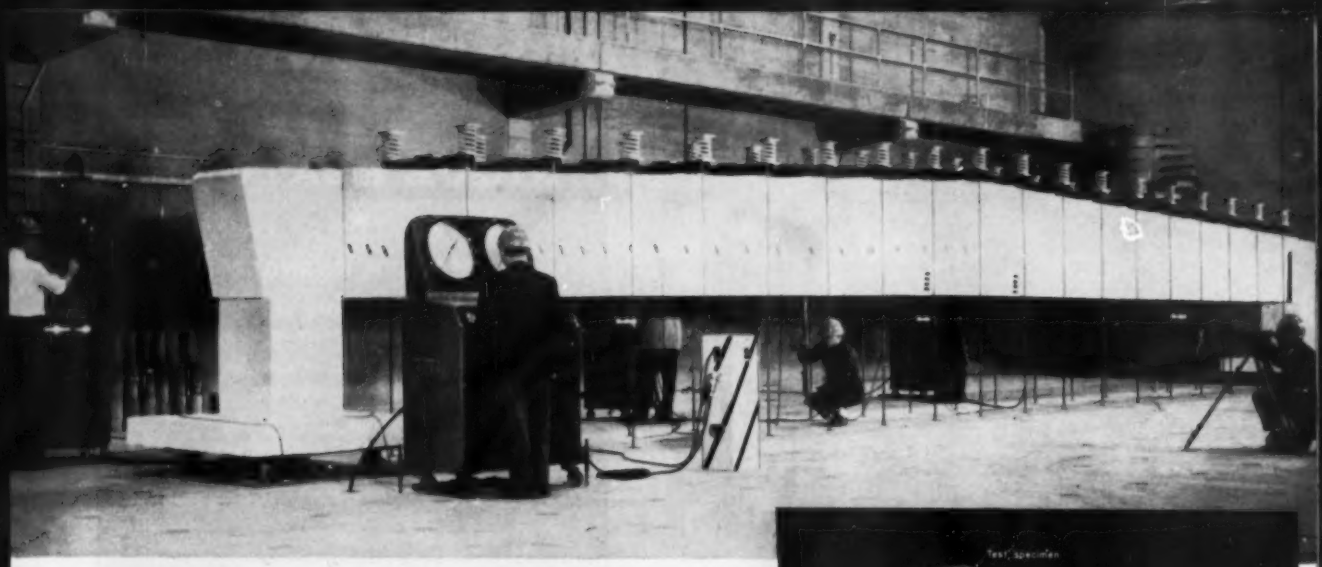
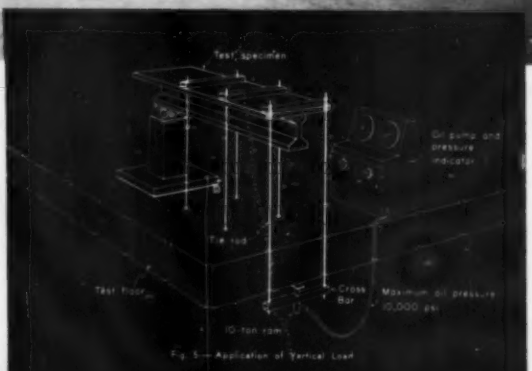
Instruments Division 750 SOUTH FULTON AVENUE, MOUNT VERNON, N. Y.

In Canada: Research & Control Instruments • Philips Electronics Industries Ltd. • 116 Vanderhoof Ave. • Leaside, Toronto 17, Ont.

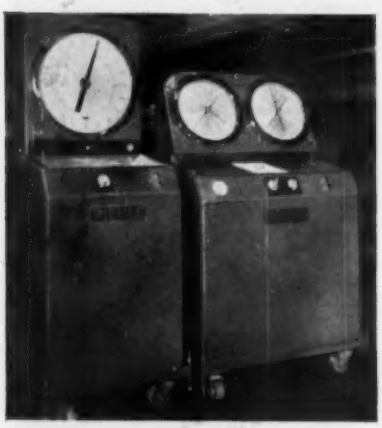


This laboratory is a giant testing machine in itself

Designed to accommodate a wide range of concrete specimens, from small beams to large structural assemblies, this hydraulic testing machine utilizes the building floor as an integral part. 690 holes in the floor permit versatile arrangements of tie rods which connect load applicator bars to a series of 10-ton rams below floor level.



Custom designed concrete testing machine at Portland Cement Association's Research and Development Laboratories, Skokie, Illinois. Diagram shows hydraulic mechanics.



From below the floor . . . load delivered by RIEHLE units

Mounted on casters, mobile RIEHLE pump and indicator units provide a compact, simple power supply for the rams. A minimum of interconnecting lines and fittings are used to reduce setup time and eliminate major maintenance problems.

Available in capacities from 10,000 to 400,000 pounds, RIEHLE hydraulic units meet your most exacting requirements for either complete standard testing machines or for custom designed equipment.

Available from RIEHLE . . . Hydraulic and Screw Power Universal Testing Machines, Creep, Stress Rupture and Fatigue Testing Machines, Impact, Brinell, Torsion, Construction materials, Horizontal Chain, Rope and Cable Testing Machines, Portable Hardness Testers for Rockwell Readings, Etc.

Riehle® TESTING MACHINES

DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

"One test is worth a thousand expert opinions" TM

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Division of American Machine and Metals, Inc.
Dept. MP-1159, East Moline, Illinois

Please send free literature on RIEHLE Testing Machines.

_____
(Type of Machine)

NAME _____

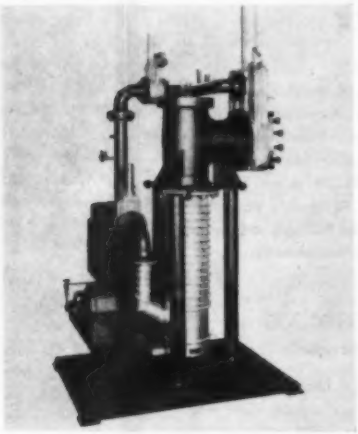
COMPANY _____

CITY & ZONE _____ STATE

APPLICATION and EQUIPMENT new products

Vacuum Pumps

General Vacuum Corp. has announced a line of packaged high-vacuum pumping systems. The 2, 4, and 6-in. models are caster-mounted, while the 10, 16, and 32-in. models are complete skid-mounted assemblies. All



are complete with manifolding, valves, air and water piping, wiring and controls ready to be coupled to the system to be evacuated. This line of pumps is for high-vacuum work, and uses diffusion pumps with mechanically refrigerated or liquid-nitrogen cooled traps.

For further information circle No. 1029 on literature request card, page 48-D.

Tracer System

A new two-dimension tracer system has been announced by Seneca Falls Machine Co. The system is electromechanically controlled and will follow any contour around a 360° path at a constant speed, regardless of direction. The cutting speed can be varied manually, or can be automatically controlled as a function of spindle speed to maintain a constant feed rate. The tracer is available as a package and can be adapted to existing machine tools. It incorporates a rotating eccentric stylus design. The stylus assembly on contact with the template, continuously feeds electrical signals to X and Y axis servo drives. These low power signals are boosted to actuate a mechanical amplifier which controls table movement.

For further information circle No. 1030 on literature request card, page 48-D.

Surface Hardness

A new Rockwell-scaled hardness tester for checking surface hardness has been announced by Kern Products Co. It is 10 in. long and weighs less than 1 lb. A steel ball of exact weight and hardness is dropped from a predetermined height, to obtain a reading on the Rockwell C scale. No setup time is necessary and little specimen preparation is needed. The instrument is portable and can be used to check unwieldly parts, inaccessible to bench-type hardness testers.

For further information circle No. 1031 on literature request card, page 48-D.

Heat Treating Furnaces

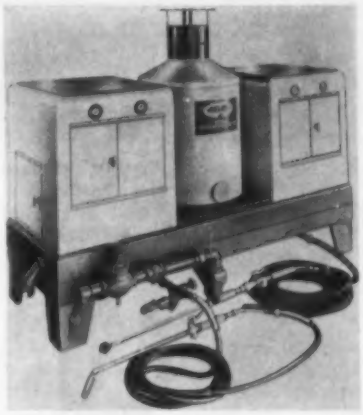
Charles A. Hones, Inc., has announced a new range of 2250 to 2400° F. for its oven furnace. The modified hearth-type furnace has atmospheric gas burners. Its venturi air-mixer

burner design permits operation without blower, compressed air or other power. By firing across the underside of the silicon carbide hearth, the flame does not come in direct contact or impinge on the work.

For further information circle No. 1032 on literature request card, page 48-D.

Steam Cleaning

A new steam cleaning machine for cleaning and phosphatizing large



structures and equipment has been announced by Kelite Corp. The new machine is available in a direct-fired model fueled with natural, manufactured, or LP gas and a fireless model that draws live steam from the plant steam system. The direct-fired model consists of a round heat exchanger, which is eliminated in the fireless model, flanked by a rectangular unit on each side. The unit at the left has two solution tanks, one for an alkaline steam cleaning composition and the other for a neutral cleaner. The unit at the right has the acid phosphate solution tank.

For further information circle No. 1033 on literature request card, page 48-D.

Refractory

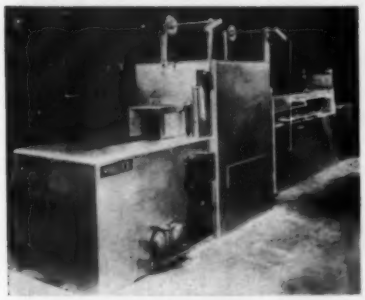
A new castable refractory designed for use in very severe conditions has been announced by Plibrico Co. Plicast 40 has a service temperature limit of 3300° F. and a service range of from 200 to 3300° F. The material has a 96% alumina content and a low iron content that broadens its range of application to include controlled-atmosphere uses. The refractory weighs 165 to 170 lb. per cu. ft. in place.

For further information circle No. 1034 on literature request card, page 48-D.

Brazing and Sintering Furnace

A continuous brazing and sintering furnace equipped with gas curtains to provide protective atmosphere for the

entire length of the heating and cooling chambers has been announced by Waltz Furnace Co. Curtains function at the entrance door of the 4-ft. heat-

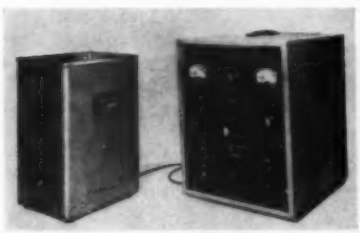


ing chamber and at the exit end of the 10-ft. cooling chamber. A mesh belt carries workpieces under a preheat hood, through a door into the heating chamber, 12 by 8 by 48 in. in size. The chamber is heated to a maximum temperature of 2300° F. by eight vertically mounted globar elements. The cooling chamber is enclosed on all sides by a minimum of 2-in. of water. Two water inlets and two atmosphere inlets are provided.

For further information circle No. 1035 on literature request card, page 48-D.

Ultrasonic Cleaning

National Ultrasonic Corp. has announced a new unit for use where high energy density ultrasonic cleaning is required. This cleaner features a 5-gal. tank 12 by 12 by 9 in. Driving elements cover 44½% of the tank bot-



tom. Actual radiating surface is 48 sq. in. The generator delivers an average power output of 250 w. and produces peaks of 1000 w. A timer, one-tube oscillator, provision for remote control of equipment and front panel switching are featured.

For further information circle No. 1036 on literature request card, page 48-D.

Stainless Steel

Universal-Cyclops Steel Corp. has announced a new grade of straight-chromium stainless steel strip designated Uniloy 435. Similar to Type 430, it has better workability when used in stretch bending and deep drawing. The improvement in physical properties is obtained by a small alloy addition and the application of newly developed processing techniques. Base price is 42¼¢ per lb.

For further information circle No. 1037 on literature request card, page 48-D.

Electrodes

Saturn Metallurgical Industries has announced new electrodes for spark machining and joining of hard-to-weld metals. Tests indicate that 1 cu.cm. of Sparkal-X tungsten alloy electrodes will remove 3.75 cu.cm. of hard metal. Electrodes are available with flat tips, round ends and offset ends in round sizes from 5/32 to 25/32 in. and in square sizes from 19/32 to 1-3/16 in.

For further information circle No. 1038 on literature request card, page 48-D.

Electric Hydraulic Press

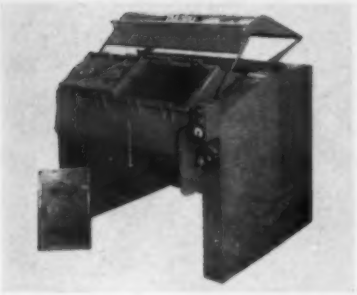
A new 60-ton electric hydraulic press for bending, straightening and pressing requirements has been announced by the ACCO Equipment Div., American Chain & Cable Co. It will handle jobs requiring pressures up to 60 tons. A by-pass valve, which has been set at the factory, will prevent the operator from overloading or damaging the press. A Helicoid gage is also inserted into the pressure line to instantaneously record all pressure readings during operation. A 7⅛-in. ram stroke at a ram speed of 25 in.

per min. at zero load and 17 in. per min. at capacity is standard when using the 5-hp. drive motor.

For further information circle No. 1039 on literature request card, page 48-D.

Barrel Finishing

A new horizontal barrel finishing machine has been announced by the Baird Machine Co. A steel plate guard which covers the barrel when it is in operation, swings out of the way to make the barrel opening accessible. Since the machine is less than 4 ft.



high, all loading and unloading can be done over the top of the machine. The Finishmaster is mobile. It is equipped with a lifting plate under the drive unit so the entire unit can be lifted with a fork lift truck.

For further information circle No. 1040 on literature request card, page 48-D.

Tubing of Reactive Metals

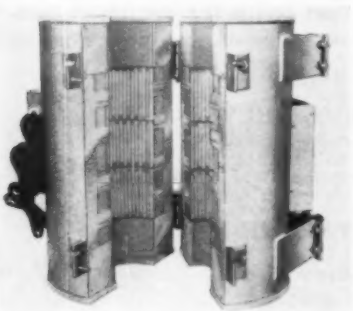
Superior Tube Co. has announced the availability of columbium, tantalum and vanadium tubing. This tubing is classified as special analysis tubing, the raw material not normally being carried in stock but ordered against customer orders. The tubing is furnished in the seamless grade and in the fully annealed, half-hard drawn and full hard, as well as in intermediate tempers, in sizes from 0.012 to 1.125 in. O.D.

For further information circle No. 1041 on literature request card, page 48-D.

Tube Furnace

Hevi-Duty Electric Co. has announced a new line of standard vertical-tube furnaces for use in tensile and creep testing machines. They are available as solid tube furnaces or in the hinged-type design which allows the user to place specimens in the test rig then swing the furnace into position and clamp it around the test piece. Maximum temperature ranges are 1850, 2200, or 2600° F. Heating chambers can be divided into three or more zones of control, each zone regulated by a variable transformer with stepless control. Multiple unit heating units heat 1850 and 2200° F. furnaces. Silicon carbide rods, mounted at right angles to the axis of the heating chamber, are used on the 2600° F. tube furnace.

For further information circle No. 1042 on literature request card, page 48-D.



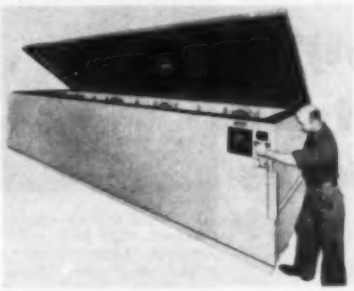
Oil Quenching

An automatic water monitoring device to detect the presence of water in oil quenching tanks has been announced by Ipsen Industries. The detector consists of a probe immersed in the oil and sealed in the tank. A replaceable resistor sensitive to water changes its electrical resistance in the order of 5:1 when subjected to emulsion moisture in excess of 0.1%. This relatively great change permits safe triggering of an alarm system.

For further information circle No. 1043 on literature request card, page 48-D.

Environmental Chamber

Webber Manufacturing Co. has announced an environmental chamber with an interior capacity of 280 cu. ft. and the ability to cool a 20,000 lb. piece of steel 215° F. A planned programming temperature control determines the rate of cooling. The chamber is designed to permit use of an overhead crane for loading, unloading or moving of the unit. The lid of the 280-cu.ft. chamber is powered by pneumatic cylinders. The refrigeration unit assembly is located approximately 25 ft. from the chamber. It starts to chill the steel in less than 5 min. after the unit is energized.



For further information circle No. 1044 on literature request card, page 48-D.

Solders

A new line of soft solder preforms for automatic soldering at temperatures ranging from 158 to 1800° F. has been announced by Alloys Unlimited, Inc. Manufactured from the tin-lead, indium, silver, precious metals and fusible alloys containing bismuth and cadmium, the preforms are available as rings, disks, washers, pellets, castings, balls and spheres, and special shapes. They are designed to be preplaced manually or automatically in the assembly prior to the heating phase of the soldering operation. To eliminate the need for ex-

ternal fluxing, a core of either acid or rosin flux is added to preform rings and pellets. The ball or sphere-shaped preform will feed automatically.
For further information circle No. 1045 on literature request card, page 48-D.

Tumbling Barrels

Custom-constructed stationary and portable tumbling barrels for cleaning and chemical treating of metals have been announced by Wiretex Mfg. Co. A heavy-duty motor and a reducer regulate the immersion cycle. Motors

from ¼ hp. up are available. Barrels ride on a shaft with ball-bearing pillow blocks. Shaft and baskets are constructed of wear-resistant metals and alloys. The entire barrel is supported on a framework that is arc welded to assure maximum rigidity.
For further information circle No. 1046 on literature request card, page 48-D.

Aluminum Extrusions

Harvey Aluminum has announced the extrusion of a multiple-hollow shape measuring 24.190 by 2.485 in. It is being extruded of alloy 6061 on a 12,000 ton hydraulic press. The six-hole shape functions as a containing unit and as a supporting member, and

is being used by the electronics industry.
For further information circle No. 1047 on literature request card, page 48-D.

Wire-Straightening and Cutting Machine

A new automatic wire-straightening and cutting machine with infinitely variable speed has been announced by Mettler Machine Tool, Inc. It cuts and straightens wire ranging in diameter from 5/32 to 3/8 in. The straightening arbor is a high-speed type, with five elongated split dies and it is mounted on ball bearings for minimum vibration. Feed ranges from 50 to 200 ft. per min.
For further information circle No. 1048 on literature request card, page 48-D.

Furnace Control

The West Instrument Co. has announced the use of their electronic proportioning controller and high-limit safety instrument in Huppert furnaces for the automatic processing of metals. Both instruments have thermocouple break protection. Instruments are mounted on a panel and the operator sets the run-up cycle and control for the job to be done.
For further information circle No. 1049 on literature request card, page 48-D.

Electropolisher

William J. Hacker & Co. has announced an electropolisher for metallographic specimen preparation. The polishing table has been designed for quick exchange of electrolytes. Facili-

ties for external etching are a part of every unit. The polisher has an attachment for on-the-spot polishing and etching of large stationary objects.
For further information circle No. 1050 on literature request card, page 48-D.

Alumina Tubes

Morganite, Inc., has introduced a line of porous, pure alumina tubes for melting and heat treatment processes and research at temperatures up to 3450° F. They were developed specifically for hydrogen and cracked ammonia reducing atmospheres and are recommended for use with platinum, molybdenum or tungsten wound heating elements. Tubes are 99+% Al_2O_3,

Take advantage of Stokes

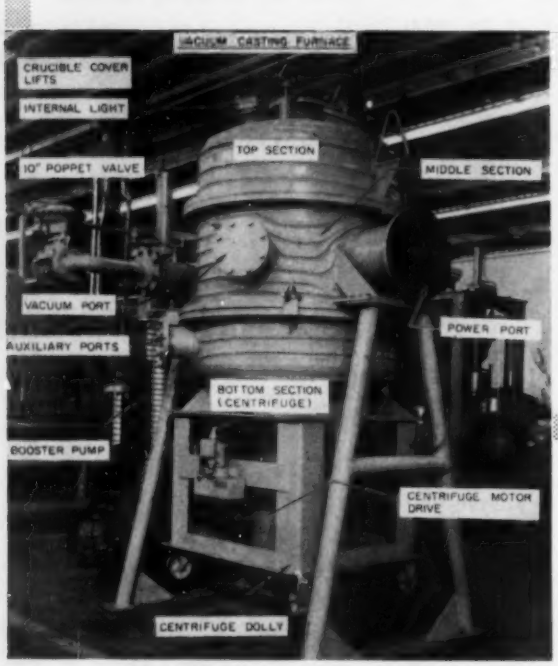
...and you profit from

From R&D to system installation and operation, Stokes unmatched technical competence and unparalleled experience assure you the most complete "package of progress" in the industry . . . with a pay-off in performance.

New vacuum methods and techniques—pioneered by Stokes—are finding more and more applications in the metallurgical field. These advances are leading industry out of old impasses . . . while reducing production costs.

Stokes equipment in the nuclear field, for example, has been used to develop new methods for plutonium melting and casting, uranium melting on a production basis, and radioactive materials handling. In another area, Stokes vacuum stream degassing equipment has already helped reduce hydrogen embrittlement in metals . . . is now pointing the way to better "killing" of steel. And still more developments are in the offing . . . in melting, refining, heat treating, sintering and brazing . . . and in Vacuum Metallizing of thin and heavy coatings for both functional and decorative applications.

Stokes experience in the manufacture of components, equipment and systems helps take the guesswork out of your operation. For instance, Stokes can supply a complete turnkey installation—erected, tested and delivered "in operation". Stokes stocks components for faster delivery to eliminate costly holdups. Standard



Radioactive materials handling investigations are safely carried out with this Stokes prototype vacuum furnace. It is remotely operated by manipulators and other external controls. This installation represents another specific requirement met through Stokes flexibility.

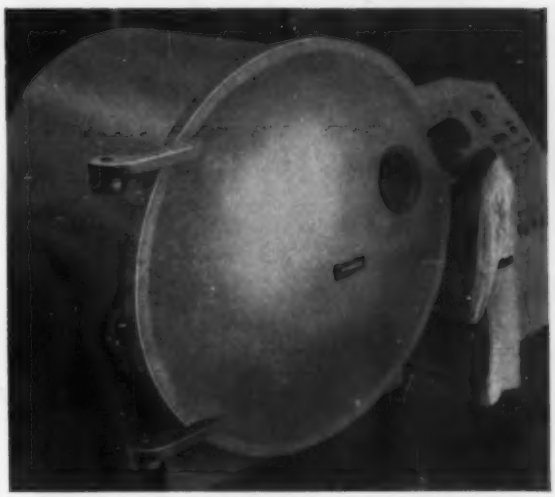
Uranium melting on a production basis is accomplished by this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of Stokes inherent flexibility.

Progress in Vacuum Metallurgy

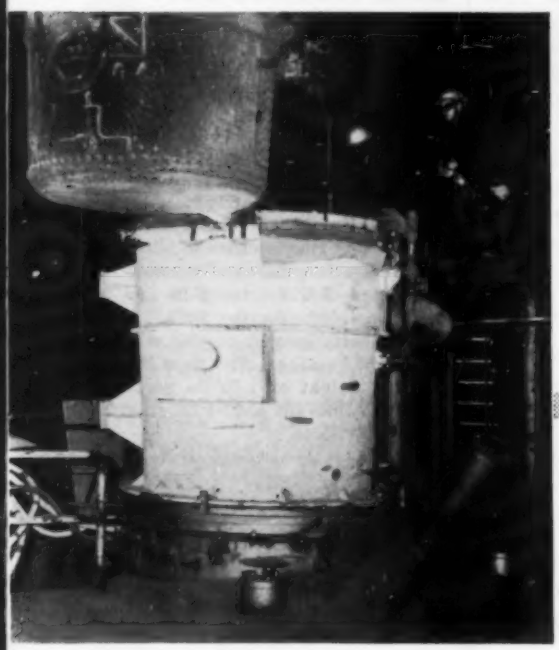
"Single Source" Service

vacuum equipment ranges from small compact R&D models to full production units. Stokes is geared to meet specific customer requirements for many types of special metallurgical equipment. All Stokes systems are offered complete, making Stokes a single source of responsibility for performance and reliability, both before and after the sale.

Let Stokes put its unparalleled experience and facilities to work for you. Stokes' Engineering Advisory Service will assist you in planning and designing an installation that will best serve your exact needs. While it's fresh in your mind, why not call Stokes . . . and get all the details.



Heavy coatings with new continuous sources—cadmium and aluminum—are now possible. Stokes manufactures a complete line of vacuum coaters . . . ranging from small R&D models to this new 72" production unit. Modifications of basic designs are easily made . . . extending applications and system size almost without limit.



First acid open hearth, vacuum stream ladle degassed—Air pouring of multiple ingots in the United States took place at Ohio Steel Foundry in May. Stokes provided the equipment. The results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

Vacuum Metallurgical Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

STOKES

have approximately 25% porosity and are available in sizes ranging up to 6 in. I.D. by 48 in. long.

For further information circle No. 1051 on literature request card, page 48-D.

Vacuum Oven

Grieve-Hendry Co. has announced a new vacuum oven with a recirculating blower for increased speed in heating before or during vacuum pumping. Vacuum to 29.5 in. Hg is provided by a rotary vane-type water-cooled pump with forced feed lubrication. Operating temperatures are to 500° F. Vacuum break is provided through a filtered inlet. Inconel sheathed heaters are used with 45-kw. input for fast heat-up, automatically reduced to 15 kw. after heaters have reached maximum surface temperature. Work chamber is 48 in. high by 72 in. long.

For further information circle No. 1052 on literature request card, page 48-D.

Fire Brick

A new insulating fire brick for use to 2300° F. has been announced by the Refractories Div. of the Babcock & Wilcox Co. The mechanical strength of the refractory has been increased by more than 65% for the K-20 and by more than 50% for the K-23. It can be fitted with hangers or pins without danger of breakage. The K-20 has an average weight of 1.70 lb. per 9-in. straight, while the K-23 9-in. straight averages 1.85 lb.

For further information circle No. 1053 on literature request card, page 48-D.

Shell Mold Furnaces

Alexander Saunders & Co. has announced a new furnace for high firing shell investment molds. The furnace has gas-fired atmospheric burners with indicating pyrometer, 1800° F. temperature, alloy grid hearth, trap-door bottom, water-filled pan to collect molten wax, and counterweights on all doors for easy operation. Over-all dimensions are 36 by 41 by 72 in.

For further information circle No. 1054 on literature request card, page 48-D.

. . . HEAT-PROCESSING - 1960 . . .

CAMBRIDGE METAL-MESH BELTS help you beat *today's* profit squeeze—give you the low-cost production and high product quality needed for the *competitive 60's!* Combined movement and processing speeds up annealing, quenching, washing, sintering, copper brazing, hardening, other operations. You cut labor costs, handling, production time.

Quality is consistent because liquids, gases flow through the belt and around product for thorough treatment.

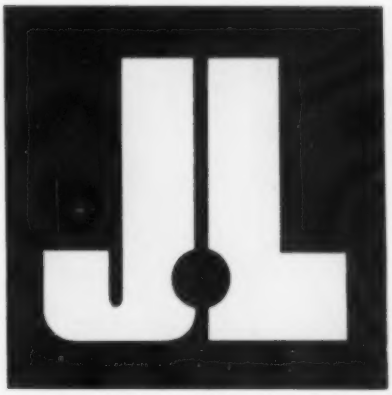
You save on operating costs, too. Superior belt design and manufacturing techniques mean longer life, fewer repairs. Belts can be made heatproof or acidproof —in any mesh, weave, metal or alloy— with any side or surface attachments.

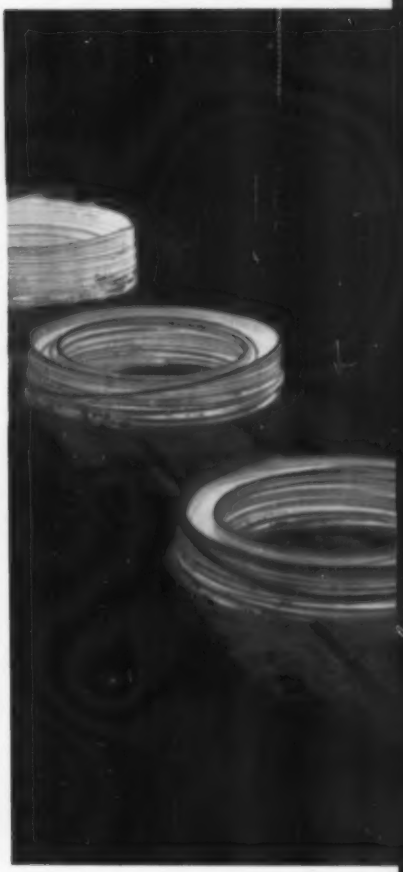
Call your Cambridge Field Engineer now. He'll be glad to discuss any aspect of Cambridge Belts—from manufacture to installation and service. Look in the yellow pages under "Belting, Mechanical". Or, write for FREE 130-PAGE REFERENCE MANUAL.

The Cambridge Wire Cloth Co.

Department B • Cambridge 11, Md.

Manufacturers of Wire Cloth, Metal-Mesh Conveyor Belts, Wire Cloth Fabrications





Pittsburgh Works bar mill—where scrapless nut quality hot rolled steel bars are tailor-made for any nut application.

We may not know your production equipment
We may not know your product application
We may not know anything about your specific requirements

. . . but we want to

and, we do know all about scrapless nut quality hot rolled steel bars

and the techniques in metallurgy and in nut-forming that result in smoother production runs, fewer rejects and less waste. We know how to achieve the precise balance and uniformity in steel bars to provide you with the best combination of nut-forming properties. We can assure optimum metal flow characteristics and shear strength so that the steel will cold work easily and will not crack. We control steel to low rates of strain hardening so that large volumes of metal can be upset without annealing. Most important, we regard your nut-forming problems as our major challenge. . . .

and when given an opportunity to talk to you about your specific operation, we'll know how to develop exactly the right steel to meet your needs. We invite your inquiry. Please write . . .

Jones & Laughlin Steel Corporation

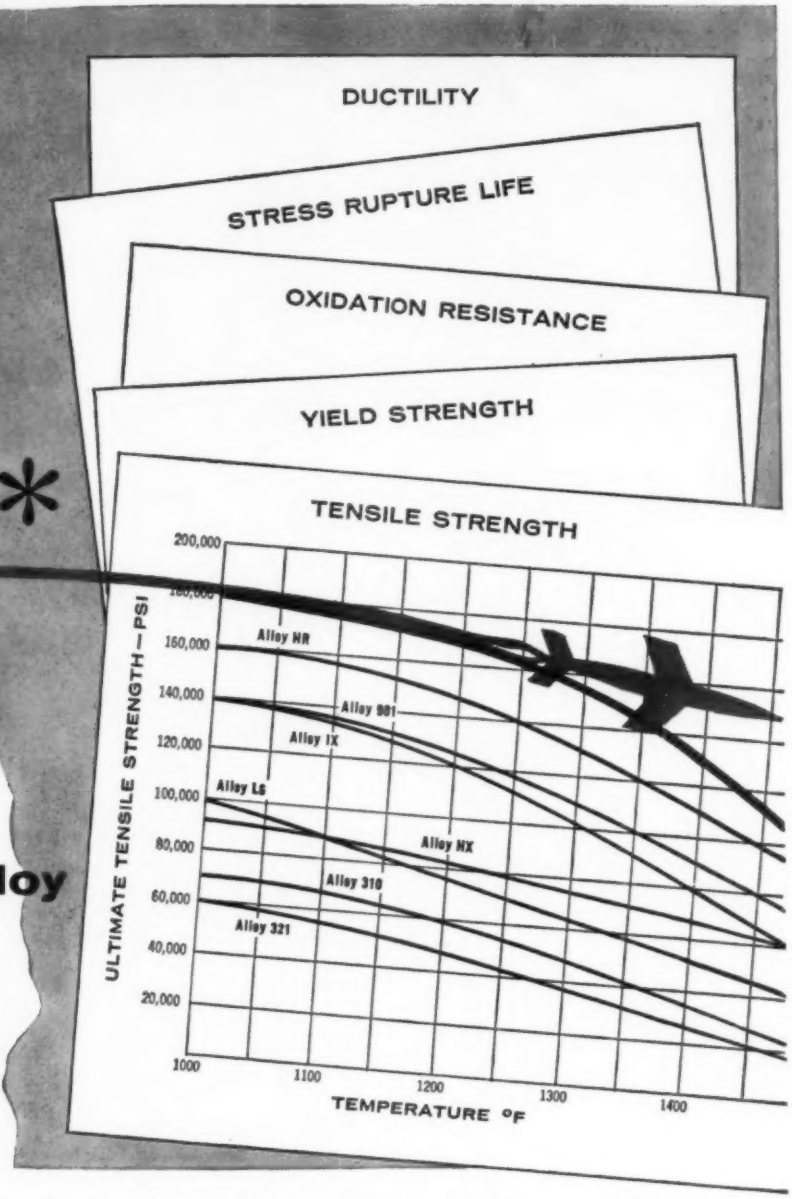
3 GATEWAY CENTER
PITTSBURGH, PENNSYLVANIA

HIGH

on every chart:

RENÉ 41*

most dependable alloy in use today in the 1200°- 1800° F range



In *all* ways, René 41 is a remarkable alloy. No other high-temperature alloy used in production today equals its tensile strength. In other properties, too, René 41 is far ahead of the field.

Also important, this nickel-base, vacuum-melted alloy is easy to work with. It's readily formable by drawing, bending, spinning — welds to similar or dissimilar materials.

Cannon-Muskegon offers René 41 in standard 36″x 96″ sheets .015″ to .125″ thick, in smaller sizes down to .010″, in bar stock up to 3″ in diameter . . . foil down to .001 in thickness . . . and fine wire only .0015 in diameter.

For complete details, write for Technical bulletin No. 86.

*TM of General Electric Co.

ULTRAMET
VACUUM ALLOYS

CANNON-MUSKEGON CORPORATION

2879 Lincoln Avenue • Muskegon, Michigan

METALLURGICAL SPECIALISTS

1-59

PHOTO BY KARSH OF OTTAWA

"Supplier reliability is a must to sound product development"

—R. W. SWANK, Research and Development, Smith-Erie Div., A. O. Smith Corp.

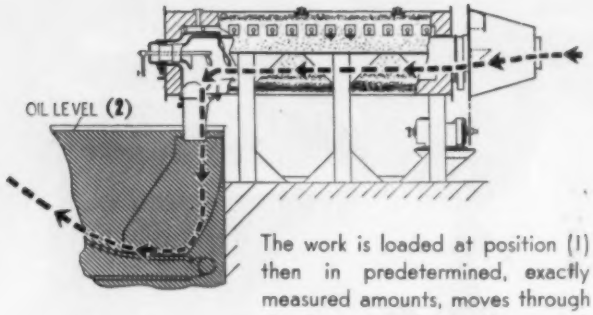
"We count Sharon Steel as one of our most dependable suppliers, and this is extremely important to a development engineer," says R. W. Swank, Manager of Research and Development of service station pumps in the Smith-Erie Division of A. O. Smith Corp.

Shown here with P. R. Fishburn, Manager of Manufacturing, Swank points out "If we can design with the knowledge that we need not be concerned about material analysis variation, our jobs are made that much easier. We've found we can expect this kind of supplier reliability from the *Sharon Steel Corporation, Sharon, Pa.*"

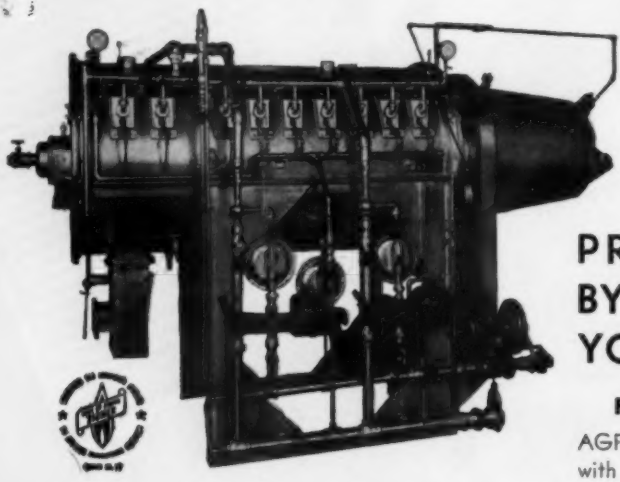
SHARONSTEEL **SHARON** *Quality* **STEEL**

IT IS NOW POSSIBLE TO PUT YOUR HEAT TREATING FURNACE IN YOUR PRODUCTION LINE BY INSTALLING

AGF AUTOMATIC CONTINUOUS FURNACES



The work is loaded at position (1) then in predetermined, exactly measured amounts, moves through the furnace and into the quench tank (2) thence out by conveyor to heating, washing, tempering or any desired further treatment.



AGF AUTOMATIC CONTINUOUS FURNACE
Model 136 utilizes a Rotary Retort and has a heat treating capacity of 150 to 400 pounds per hour. Larger models are available for higher production needs and single installations are now able to handle up to 1000 pounds of steel products per hour with a guarantee of uniform clean hardening.

A completely new combustion system and other engineering features permit processing ferrous or non-ferrous parts at temperatures from 600°F. to 1850°F. Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts or the heat treating of aluminum parts can be accomplished with equal ease and without any modification of the furnace.

"PIONEER inventors, designers and builders of industrial heat treating and gas tempering equipment since 1878."

PROOF IS PROVIDED BY MANY USERS, THAT YOU SHOULD CONSIDER

PRODUCTION LINE HEAT TREATING

AGF Engineers and Metallurgists have kept up with the trend to continuous automatic production. As a result it is possible to point to several important installations that are successfully providing "round-the-clock" output of startling volume.

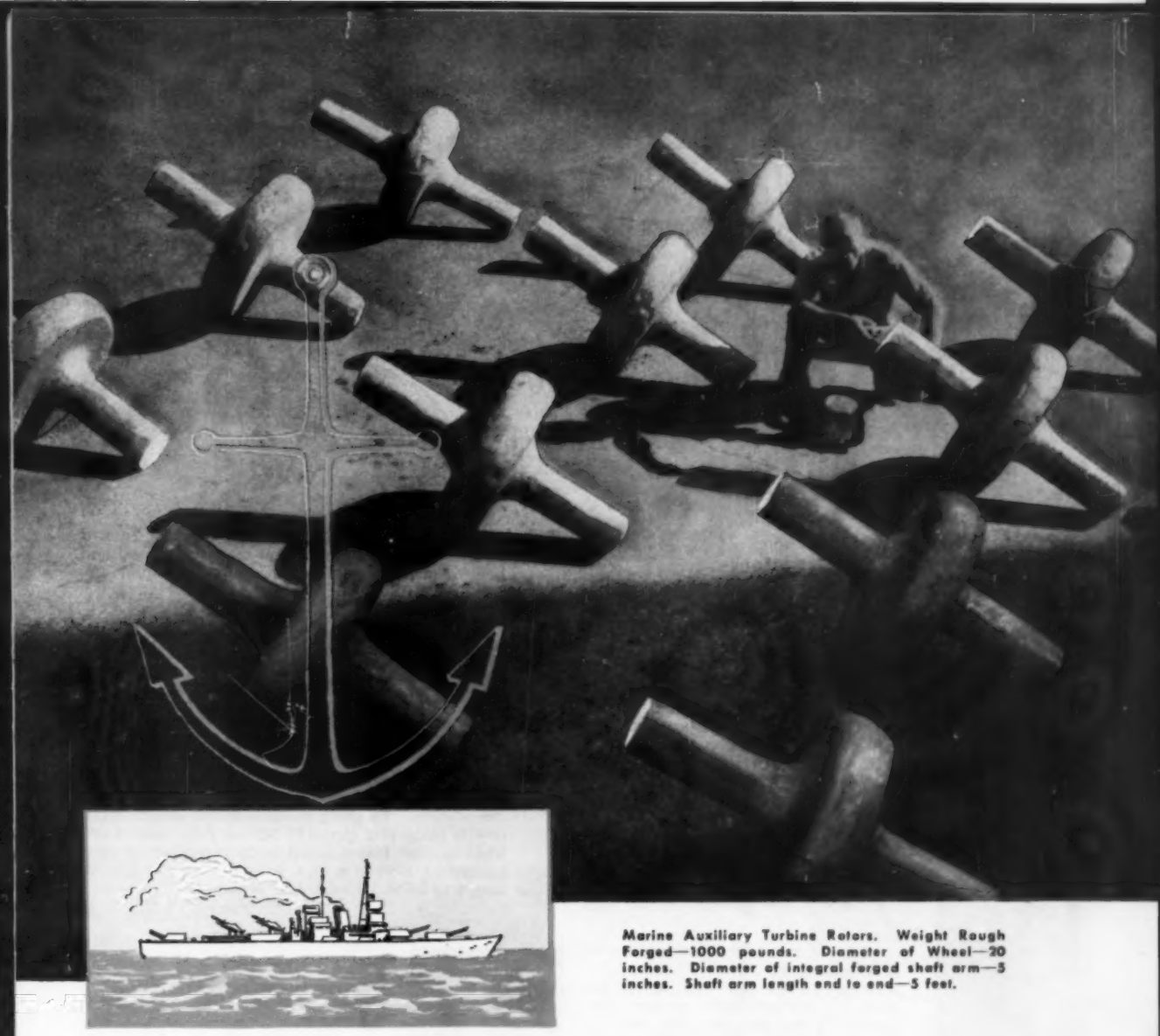
It costs nothing to present your heat treating production problem to a qualified AGF representative in your area.

AMERICAN GAS FURNACE CO.
1002 LAFAYETTE ST., ELIZABETH 4, N. J.

Please send full descriptive material upon the AGF Model 136 Automatic Furnace.

My Name is.....Title.....
Company.....
Street.....City.....
I want to heat treat.....lbs. per hr. of.....
.....

☐ I will send samples for your recommendation.
☐ Please have your representative call at no obligation to my company.



Marine Auxiliary Turbine Rotors. Weight Rough Forged—1000 pounds. Diameter of Wheel—20 inches. Diameter of integral forged shaft arm—5 inches. Shaft arm length end to end—5 feet.

Forged Alloy Steel Rotors Sail the Seven Seas . . .

These forged alloy steel rotors will show up at the heart of auxiliary turbines driving boiler feed pumps on large maritime and naval vessels. Rough machined, they weigh slightly less than 1000 pounds each.

Here is visual proof of the versatility of our steel forging production capabilities . . . versatility enabling us to meet the specifications for components required by a wide diversity of industrial and marine machinery.

The same careful quality control procedures as are accorded to turbine rotors weighing 40 tons and more, are standards of operation in producing these relatively small components.

You are safe in placing your parts forgings in our hands. It will pay you well to consult with us on your requirements for any size or shape of steel forgings and castings.

ERIE FORGE & STEEL CORPORATION

ERIE, PENNSYLVANIA

C. I. HAYES SELLS MORE THAN JUST HEAT TREATING EQUIPMENT
. . . WE SELL LONG-TERM CUSTOMER SATISFACTION – WITH THE

5-point Results Guaranteed plan!

1 DETERMINE BEST PROCEDURE . . .

The Hayes Laboratory is unique . . . it allows you to take an active part . . . see the actual results . . . of procedures and operations developed to suit your specific needs. Hayes laboratory facilities . . . and the services of our entire staff . . . are available during this vital phase . . . WITHOUT COST OR OBLIGATION. Step 1 to RESULTS GUARANTEED!

2 SELECT RIGHT EQUIPMENT . . .

Your customized procedures are developed on an extensive line of full-scale *production* heat treating equipment . . . not laboratory models. The equipment that goes into your plant is identical to that you *actually saw* meet your requirements. If models of proper size are not available, equipment will be tailored to your exact needs. Step 2 to RESULTS GUARANTEED!

3 START-UP AND INSTRUCTIONS

Free start-up service by a Hayes engineer completely familiar with the procedure developed assures duplication of laboratory results. Your staff is fully instructed on how to make the operation most economical and how to maintain the equipment for maximum life. Step 3 to RESULTS GUARANTEED!

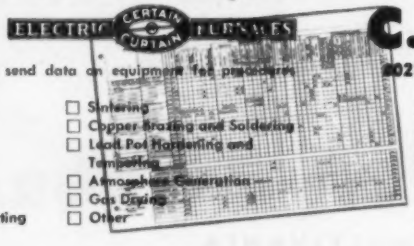
4 PROPER SERVICING . . .

Hayes is known for its prompt, competent service . . . well aware that heat treating equipment is production equipment and that downtime is costly to the customer. Hayes maintains a private plane that speeds its Service Engineers to you when needed. Hayes is just as concerned about your equipment *after* you buy it as *before* you buy it. Step 4 to RESULTS GUARANTEED!

5 MAINTAINING OPTIMUM OPERATION . . .

Hayes maintains an extensive inventory of stock parts . . . your assurance that the equipment can be maintained in optimum operating condition long after competitive equipment has become obsolete or worn out. Because highest quality materials are used, less frequent rebuilds are required. Relatively few Hayes furnaces appear on the used-furnace market . . . proof that customers buy 'em, like 'em, hang on to 'em! Step 5 to RESULTS GUARANTEED!

Solve your heat treating problems the RESULTS GUARANTEED way! Request bulletins for complete data on any of the famous C. I. Hayes CERTAIN CURTAIN electric furnace line.



FREE LITERATURE: Please send data on equipment for procedures checked.

- ☐ High Speed Hardening
- ☐ Tool Steel Hardening
- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Vacuum Heat Treating
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Generation
- ☐ Gas Dexing
- ☐ Other

C. I. HAYES, INC.
202 WELLINGTON AVE., CRANSTON 10, R. I.

FURNACE and ATMOSPHERE
SELECTION CHART . . .
YOUR'S For The Asking
. . . WRITE TODAY!

APPLICATION and EQUIPMENT new literature

1056. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

1057. Abrasive Wheels
Recommendations for abrasive, grit, grade and bond, for wheels for grinding more than 1600 materials in 57-page catalog. *Abrasives Div., Carborundum Co.*

1058. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

1059. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1060. Aluminum
Brochure describes production equipment, products, research facilities of aluminum plant. *Anaconda Aluminum*

1061. Aluminum
16-page bulletin lists sizes, weights, lengths of aluminum in rod, bar, plate, sheet. Guide to selection, finishes, mechanical properties. *Ryerson*

1062. Aluminum Bronze
8-page booklet on study that led to development of one-piece, nickel-aluminum bronze ship propeller. *International Nickel Co.*

1063. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

1064. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

1065. Aluminum Products
8-page brochure on available cold processed rod and screw machine stock. Advantages, properties. *Metals Div., Olin Mathieson Chemical Corp.*

1066. Aluminum Tubing
New 48-page book on aluminum tubing. Alloys, properties, selection, applications. *Revere Copper & Brass Co.*

1067. Annealing
Bulletin SC-146 on cycle annealing in atmosphere and direct-fired furnaces. Steels annealed and hardnesses obtained. *Surface Combustion*

1068. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever Co.*

1069. Atmosphere Furnace
Bulletin HD-1 on batch-type controlled atmosphere furnace. Specifications, atmosphere circulation. *Dow Furnace Co.*

1070. Atmosphere Furnace
4-page bulletin on automatic continuous heat treating furnace. Operational advantages, principle of operation, capacity, construction. *American Gas Furnace*

1071. Atmosphere Furnaces
4-page bulletin on furnaces for hardening high carbon and high speed tool steels. Diagrams, specifications and performance data. *Lindberg Engineering*

1072. Atmosphere Heat Treating
Hydrogen and protective atmosphere heat treating of some stainless, heat resisting, beryllium and nickel alloys in Ferrotherm Newsletter. *Ferrotherm Co.*

1073. Beryllium Copper
New data sheets on three copper beryllium alloys. Analysis, physical constants, mechanical properties, heat treating procedures. *Pennrold Div., Brush Beryllium*

1074. Blast Cleaning
8-page bulletin 1403 on liquid blast cleaning equipment. Drawings of cabinets. *Pangborn Corp.*

1075. Brass
Publication B-39 on superfine-grain drawing brass. Properties. Finishing characteristics. *American Brass*

1076. Brazing Alloys
Data on brazing stainless alloys. *Wall Colmonoy*

1077. Brazing Stainless
24-page booklet discusses characteristics of base and filler metals, brazing cycles, selecting and using gas atmospheres, construction and application of various types of furnaces. *Harper Electric Furnace Corp.*

1078. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

1079. Chromium Plating
Bulletin CFC-1 on advantages of crack-free chromium plating process. *Metal & Thermit*

1080. Clad Extrusions
6-page Bulletin 10 on extrusions of two combined metals. Combinations available, techniques of production. *Nuclear Metals*

1081. Cleaners
Folder on immersion, electrolytic, spray cleaners, phosphate coaters, strippers, drawing compounds, additive agents. *Northwest Chemical*

1082. Cleanliness Tester
Bulletin S-510 on instrument that measures degree of cleanliness of metal parts. *Branson Ultrasonic Corp.*

1083. Cleaning and Finishing
New 40-page catalog on drum, conveyor, monorail, barrel finishing equipment. Complete finishing systems and special machines. *Ransohoff Co.*

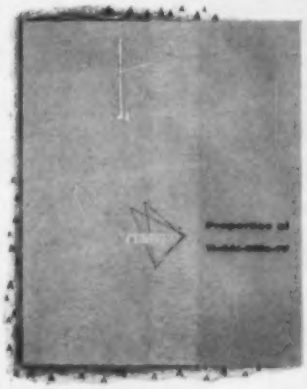
1084. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

1085. Cold Rolling
Description of advantages of cold rolling of ship propeller shafting. How it is done. *Erie Forge & Steel*

1086. Combustion Safeguard
Folder on Protectofier for protection against fires or explosions in furnaces. Components, operation, advantages. *Protection Controls, Inc.*

1087. Compressors
12-page Bulletin 126-B on application of turbocompressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

1055. Titanium Alloy
Properties of Ti-4Al-3Mo-1V, a heat-treatable titanium alloy, are discussed in this new 24-page bulletin. Besides physical and mechanical properties, heat treating, design properties, forming and fabrication, and welding of the alloy are discussed. Considerable detail is included in the treatment of each subject. For instance, under forming of solution-treated sheet, such subjects as bending, springback, stretching, hydropress-rubber forming, drop hammer forming, joggling and dimpling are discussed. *Titanium Metals Corp. of America*



1088. Controllers
16-page Bulletin No. 9 gives data, operation diagrams, schematic drawings of capacitrols. *Wheelco*

1089. Copper Alloys
New 8-page folder gives sizes, pounds per foot, alloy specifications for rectangular and square bars. *Titan Metal Mfg.*

1090. Copper Wire
Revised bulletin T-3 on properties, advantages and applications of nickel-clad copper wire. *Riverside-Alloy Metal Div., H. K. Porter Co.*

1091. Crucible Melting
Nontechnical bulletin on crucible melt-

"GAS gives us the controllability, cleanliness, economy and speed we demand"

A. O. Smith Corporation

Lengths of oil well casing are in production at the A. O. Smith Corporation in Milwaukee. They are being stress relieved in a gas furnace.

Gas has proved best on A. O. Smith's production line because of its cleanliness, controllability, speed and economy. Gas gives nearly 50% reduction in cost over their previous fuel, and carbon spots have been eliminated. There are three pre-heat furnaces that heat the pipe to 1650°-1750°, depending on the size of pipe. Three re-heat furnaces bring the temperature back up before quenching.

A. O. Smith also produces auto frames, pressure vessels, glass lined farm storage units and tanks, glass-lined gas water heaters and furnaces. Throughout their operations, gas is installed as an integral, indispensable part of their production lines.

For information on how gas can help you in your production operations, call your gas company's industrial specialist. He'll be glad to discuss the economies and superior results you get with modern gas industrial equipment. *American Gas Association.*

ing gives standard nomenclature, chapters on furnace maintenance, burner design, charging and melting, and other factors. *Crucible Manufacturers' Assoc.*

1092. Crucibles
Bulletin Cl-55 on crucibles for service to 2900° F. *McDanel Refractory Porcelain*

1093. Cutting Oil
Folder describing nine types of cutting oils for varied applications. *Gulf Oil Corp.*

1094. Degreaser
Folder on automatic degreaser. Cleaning and solvent cycles described. Features of equipment. *Detrex*

1095. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1096. Degreasing
New 36-page bulletin 44A on trichlorethylene for vapor degreasing and other uses. Procedures in various equipment, properties, safety measures. *Hooker Chemical Co.*

1097. Dilatometers
Bulletins on photographic and mechanically recording dilatometers. Special features. *Cooke, Troughton & Simms*

1098. Ductile Iron Plate
Data on ductile iron plate and properties. *Lindgren Foundry Co.*

1099. Ductile Irons
New pamphlet on alloys for ductile irons. Table of grades with mechanical property ranges. *Vanadium Corp.*

1100. Electric Heaters
New 64-page catalog on complete line of electric process heaters and their uses. *E. L. Wiegand*

1101. Electrolytic Etching
12-page article in Metal Digest, V. 1, No. 2, covers the theory and practice of electrolytic etching of metallographic specimens. *Buehler, Ltd.*

1102. Electron Microscope
24-page booklet on use of electron microscope in science and industry. *RCA*

1103. Electronic Tracer
New booklet on photocell tracer for automatic cutting. Features and advantages. *Linde*

1104. Electroplating
12-page booklet on nine ways to cut electroplating costs. Surface preparation, how to select proper compound, determining solution life, rinsing, racking. *Diversey Corp.*

1105. Electroplating
Chart gives reference data for gold, rhodium, palladium, platinum, silver, nickel plating. *Technic*

1106. Electroplating
4-page brochure describes process for plating selected areas without immersion tanks. *Sifco Metachemical*

1107. Environment Chambers
New folder on temperature, humidity chambers. Models, specifications. *Harris Refrigeration Co.*

1108. Extruded Parts
4-page bulletin on cold extruded metal parts. Properties, advantages, specifications. *Burgess-Norton Mfg. Co.*

1109. Extrusions
Bulletin on extruded seamless alloy and stainless steel tubing. Properties, shapes. *Metals Processing Div., Curtiss-Wright*

1110. Extrusions
2-page quarterly bulletin gives data on design and finishing of aluminum extrusions. *Precision Extrusions, Inc.*

1111. Ferroalloys
4-page folder on Chromtemp exothermic ferrochromium. Advantages, selection of analysis and grades. *Union Carbide Metals*

1112. Ferrochromium
New booklet describes function of chromium in cast iron; data on chromium alloys for ladle and furnace additions. *Ohio Ferro-Alloys Corp.*

1113. Film Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1114. Finishes
Data on production finishes for grinding, polishing and deburring of flat work. Specifications. *Hammond Machinery Builders*

1115. Forging
Brochure on Cameron forging process. *Cameron Iron Works*

1116. Formed Plate
Bulletin on stainless steel flanged heads. 246 available dies listed. *G. O. Carlson*

1117. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Products*

1118. Freezer
Data on chest for use down to −140° F. for production and testing. *Revco*

1119. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1120. Furnace Brazing
Folder gives correct procedures for furnace brazing. Design for furnace brazing, brazing materials, atmospheres. *American Platinum*

1121. Furnace Controls
Bulletin 658 on saturable reactor for regulation and control of electric ovens and furnaces. *Sorgel Electric Co.*

1122. Furnace Elements
24-page Bulletin H on electric heating elements. Tabular data on physical and electrical specifications for various sizes. *Globar Div., Carborundum*

1123. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1124. Furnaces
New 26-page Bulletin S-1056 on steel heating equipment. Uses and applications. *Selas*

1125. Furnaces
12-page reprint on design, construction and application of chain belt conveyor furnaces. *Electric Furnace Co.*

1126. Furnaces
List of used furnaces in stock. *Papesch & Kolstad, Inc.*

1127. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

1128. Furnaces
Folder describes complete setup for heat treatment of small tools, including

NOW

five big steelmakers...

have ordered pilot plants of the revolutionary Lee Wilson Opened Coil Annealing System

for a wide range of products, including tin plate, silicon and carbon steel coils, after tests at the Lee Wilson Research Center. The success of the Opened Coil Annealing System is based on economics and results. It costs less to install and operate than any comparable continuous equipment. It is a high production unit that permits exacting control of every inch of every coil, assuring the finest possible annealed product.

For your inspection, we have a 2-section mock-up of the 8-zone rotary furnace and an operating pilot unit of the batch type at our Research Center. We welcome test coils. We're sure that once you see it in operation and compare results you, too, will be convinced that the Opened Coil method is the answer to faster, better, more economical annealing.

draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

1129. Furnaces

Bulletin 5710 on conveyor furnaces for operation to 2150° F. Specifications of standard straight through and "humpback" furnaces. *C. I. Hayes*

1130. Graphite

4-page catalog section S-5050 on impervious graphite and resin-base cements for corrosive service. 2-page table gives recommendations for commercial applications. *National Carbon*

1131. Graphite

20-page brochure on significance of graphite as electrodes, anodes, molds, and specialties in electrometallurgy and electrochemistry. *Great Lakes Carbon*

1132. Graphite

Folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products*

1133. Hand Forgings

20-page brochure on availability, uses, types, sizes, alloys, tempers. *Kaiser Aluminum & Chemical Sales*

1134. Hardness Tester

Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

1135. Hardness Tester

20-page book on hardness testing by Rockwell method. *Clark Instrument*

1136. Hardness Tester

4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

1137. Hardness Tester

Catalog 506 on Frank hardness tester for Rockwell B and C, Brinell and Vickers hardness tests. *Opto-Metric*

1138. Hardness Tester

Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

1139. Hardness Tester

Bulletin F-1689-3 on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1140. Hardness Tester

Bulletin on how to test large gears with portable Brinell tester. *King Tester*

1141. Hardness Tester

18-page Bulletin DH-325 on Rockwell normal model hardness tester for measuring metals and alloys of all types and shapes. *Wilson Mechanical Instrument*

1142. Hardness Testing

Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

1143. Heat-Resistant Alloys

Data sheet on RA309 gives creep, stress-rupture and mechanical properties, composition. *Rolled Alloys, Inc.*

1144. Heat-Resistant Castings

16-page bulletin on design, foundry practice and applications. *Electro-Alloys*

1145. Heat Treat Pots

Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

1146. Heat Treating

Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

1147. Heat Treating Fixtures

24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1148. Heat Treating Fixtures

16-page Catalog M-7 on heat treating baskets and corrosion-resistant alloy fabrications. *Wiretex Mfg. Co.*

1149. Heat Treating Fixtures

32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

1150. Heat Treating Furnaces

Construction and performance data on high-temperature equipment in 6-page bulletin. *Ipsen, Inc.*

1151. Heat Treating Furnaces

New Bulletin No. HT-53 on heat treating furnaces. Construction, design, fuel used. *Carl-Mayer*

1152. Heaters

Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1153. Heaters

Bulletin GEA-6306A on immersion heaters for heating oil. Product data in table form. Circulating and non-circulating heaters. *General Electric*

1154. High-Alloy Castings

16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1155. High-Temperature Bolts

4-page bulletin on aircraft bolts for working temperatures to 1600° F. *Standard Pressed Steel Co.*

1156. Humidity Instruments

22-page bulletin on indicating recording and controlling wet and dry bulb instruments and psychrometers. *Bristol Co.*

1157. Induction Heater

8-page bulletin on 60-cycle induction heater for aluminum, copper, brass and steel. Installations, aluminum billet heater selection chart. *Magnethermic*

1158. Induction Heating

60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1159. Induction Heating

Folder 15C8053C gives advantages of induction heating and specifications and dimensions of heater. *Allis-Chalmers*

1160. Inspection

12-page booklet on Borescopes for inspection within a threaded hole, recess or interior surface. Various models and their uses. *National Electric Instrument*

1161. Inspection

Bulletin on Spotcheck dye-penetrant inspection. Advantages, prices. *Magnaflux*

1162. Investment Casting

7-page bulletin on economics of investment cast vacuum alloys tells how it is done, how much it costs. *Cannon-Muskegon, Inc.*

1163. Investment Casting

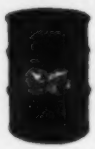
"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting*

1164. Iron Tubing

Data Memo No. 18 on ingot iron tubing gives composition, properties, treatments, applications. *Superior Tube Co.*

1165. Lab Test Dies

Complete information on multi-motion laboratory test specimen dies. *Haller*



...VCA Distributor Service — When you're in a hurry for warehouse quantities of alloys, there's a VCA distributor near you who can meet your needs completely — and *fast!* In warehouses all across the country, adequate stocks of Vancoram products are on call. Next time get the big benefits of VCA service, plus the bonus benefits of Vancoram *extra* quality! Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N. Y. • Chicago • Cleveland • Detroit • Pittsburgh

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VANADIUM CORPORATION OF AMERICA

1166. Laboratory Equipment
Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

1167. Laboratory Equipment
44-page catalog on temperature-humidity equipment including sub-zero cabinets, temperature reducing attachments and accessories. *American Instrument Co.*

1168. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

1169. Laboratory Mill
4-page reprint on rolling mill for laboratory studies, which may be operated as a 2-high, 3-high or 4-high mill. *Fenn Mfg.*

1170. Lathe Chucks
12-page catalog on geared scroll and independent hardened plate-type chucks, gives specifications, uses. *Whiton Machine*

1171. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

1172. Lithium
Technical bulletin 101 gives physical, chemical, thermodynamic properties of lithium, general information, references. *Foote Mineral Co.*

1173. Lubricant
Bulletin 421 on colloidal graphite dispersions for assembly and run-in lubrication. Wetting properties. *Acheson Colloids Co.*

1174. Machining Titanium
8-page bulletin on turning, milling, drilling, tapping, grinding. Recommendations for each. Typical properties of titanium. *Mallory-Sharon Metals*

1175. Magnesium
53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

1176. Malleable Castings
Data Unit 105 on properties and characteristics which give standard and pearlitic malleable iron castings their toughness. *Malleable Castings Council*

1177. Marking
Leaflet on where to use markers for identification purposes. *Markal Co.*

1178. Metal Cleaning
24-page bulletin reviews principles of cleaning, how to electroclean, barrel clean, machine clean, prepare metal for paint, strip paint, pickle metals. *Oakite Products*

1179. Metal Cleaning
32-page Bulletin 10,001-G on methods, materials and equipment for cleaning and preparing metal surfaces. *Magnus Co.*

1180. Metal Cutting
56-page Catalog No. 32 gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric*

1181. Metal Melting
Chart showing melting points of metals in both Centigrade and Fahrenheit. *Fansteel Metallurgical Corp.*

1182. Metal Sorting
Data on nondestructive sorting of raw, semifinished or finished parts. *J. W. Dice*

1183. Metallograph
6-page bulletin on micro-metallograph. Description and specifications. *E. Leitz, Inc.*

1184. Microhardness
Data on microhardness tester with readings corresponding to Vickers. *Newage Industries*

1185. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

1186. Microscope
Brochure SB56 on cycloptic stereoscopic microscope. *American Optical*

1187. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

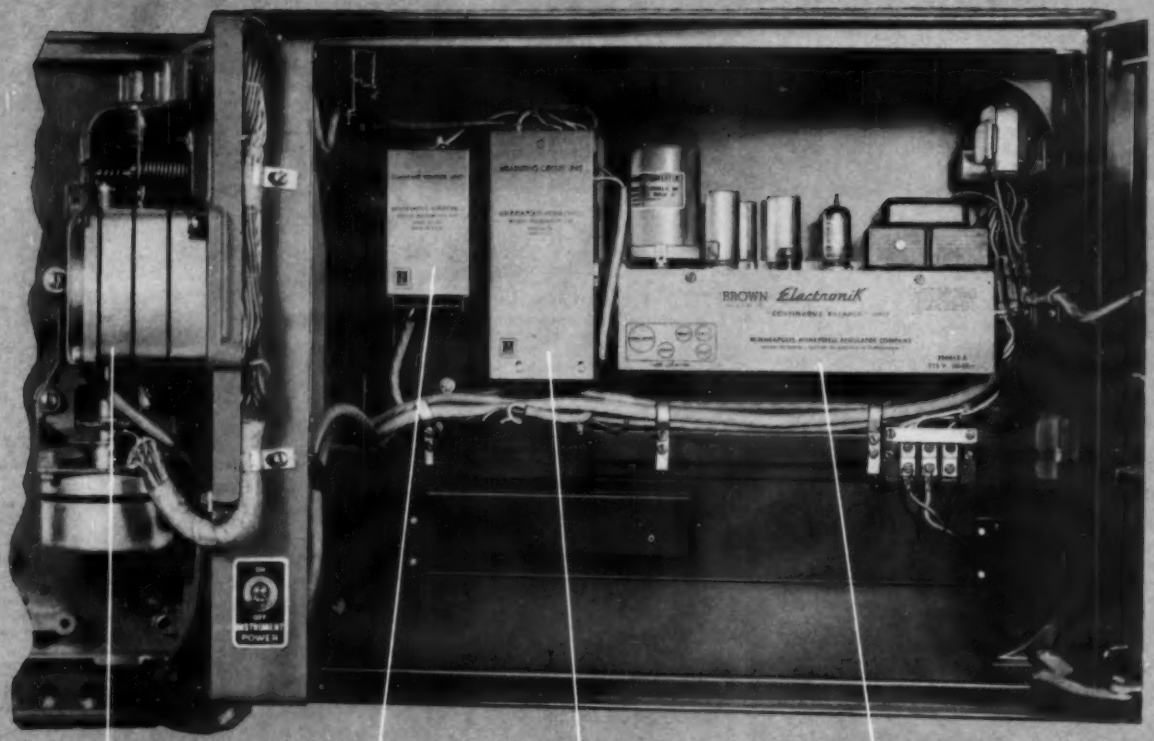
1188. Molybdenum
Catalog and price information on molybdenum products and properties. *General Electric, Lamp Metals and Components Dept.*

1189. Nondestructive Inspection
New 12-page booklet on use of X-rays and gamma rays in industry. Advantages and disadvantages of each type of radiation. *Picker X-Ray*

1190. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

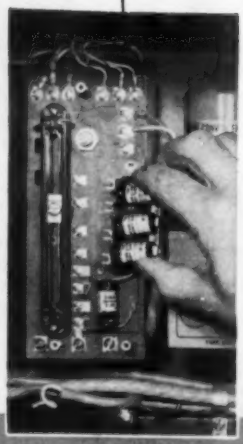
1191. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

(Continued on page 48-A)



Servo Motor has sectional housing, leakproof oil wick, printed circuits for simplified servicing. Any major part can be replaced in 2 minutes.

Constant Voltage Module—Uses Zener diodes and an ambient temperature compensator to replace standardizing mechanism.



Measuring Circuit Module—Contains easily-changed range spool panels and vernier adjustment. Range is changed simply by replacing screw-clip panels of fixed resistors.

Amplifier Module—Quick-connect design permits fast, easy removal for servicing and replacement. Circle shows quick connect plug.

THESE FOUR NEW FEATURES ARE STANDARD WITH ALL *ElectroniK* POTENTIOMETERS

New modular design...

makes ElectroniK potentiometers easier to use and maintain

Now, four great new features add new operating and servicing ease to all *ElectroniK* circular and strip chart potentiometers.

- **New servo and chart drive motors are sectionalized so that any major part can be replaced in two minutes.**
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- **A new measuring circuit, with quick-change range spools, simplifies range changing and reduces stray pickup.**
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Now, modular design is combined with the traditional precision of *ElectroniK* potentiometers, to give you a greater value than ever in accurate, dependable measurement and control.

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Honeywell

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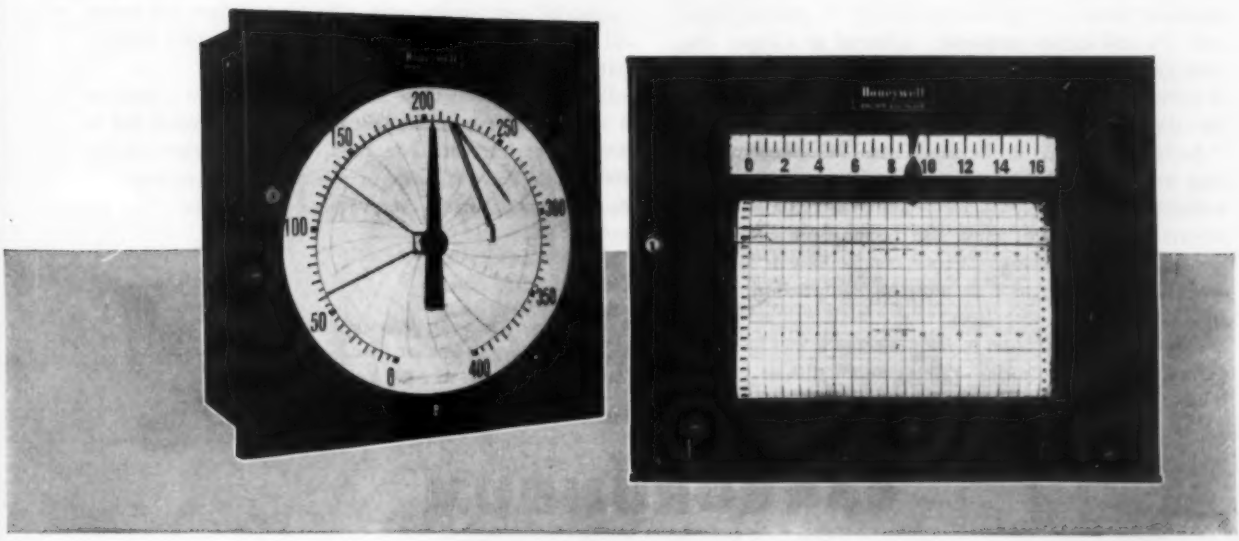
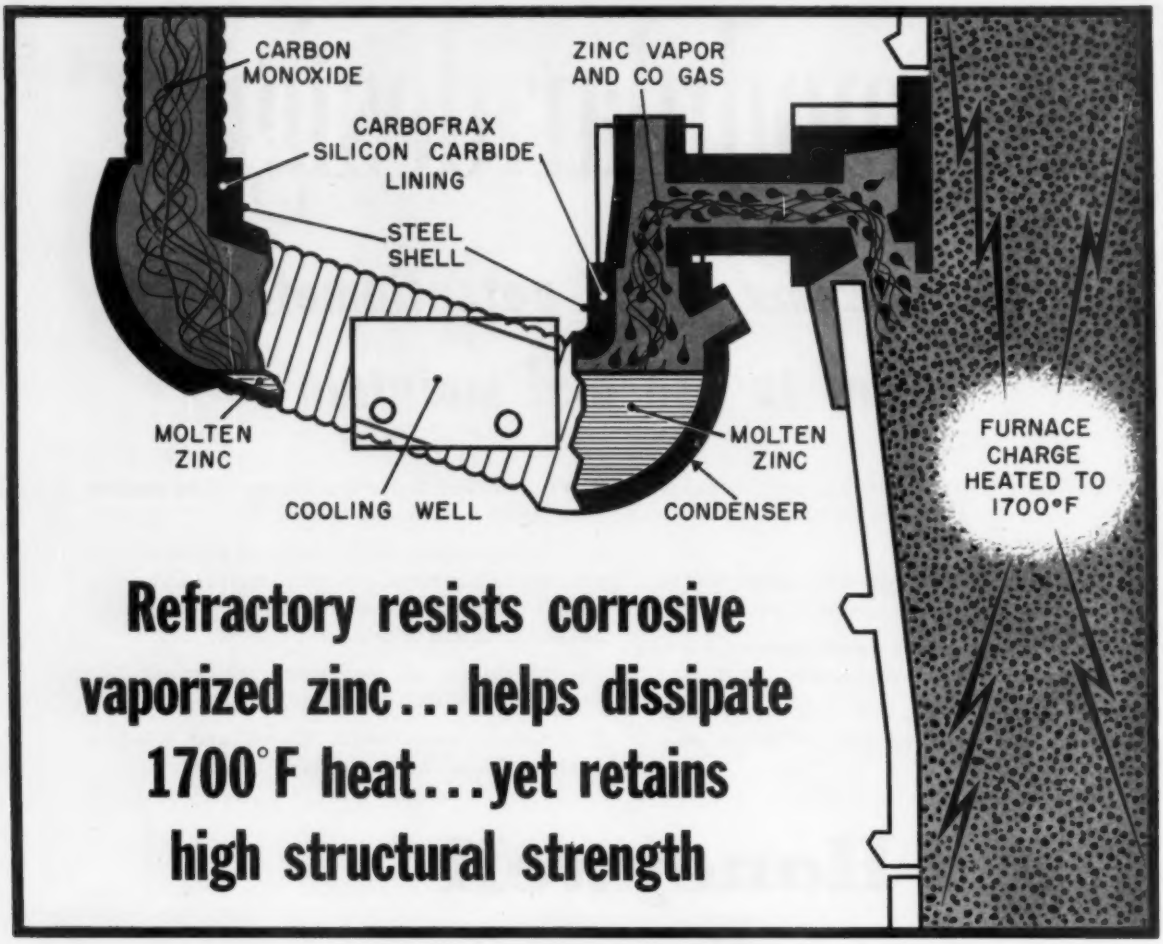


It took one of Carborundum's refractories to solve this problem:



A major producer of high purity zinc reduces zinc ore by an electro-thermic process. Sintered ore and coke, heated in a resistance furnace to approximately 1700° F, produce vaporized zinc and carbon monoxide. Collected in a vapor ring, these gases pass into a condenser containing a large amount of molten zinc. Here, the vaporized metal is condensed and the carbon monoxide exhausted.

Refractory linings for the vapor ring, condenser and tapping well must not only possess high hot strength, but also withstand the intensely corrosive action of the molten and vaporized metal. They must also be impermeable to gas seepage. In addition, high thermal conductivity is required, since huge amounts of heat must be dissipated to obtain rapid cooling of the zinc vapor.

This tough combination of requirements is met by one of Carborundum's refractories—CARBOFRAX® silicone carbide. It has exceptional load bearing strength at high temperatures (300 psi at 2750° F without crushing) and almost complete impermeability to gases. CARBOFRAX refractories are also chemically inert—resist most acids, acid sludges and fluxes, and molten and vaporized zinc. Moreover, thermal conductivity is high—11 times greater than fireclay.

Properties such as these may be the answer to a problem in your plant. If even the best of standard materials fail to give the performance you need, consider Carborundum's refractories. There is a wide range of products to meet the requirements of almost every type of application.

Write today for your free copy of "Super Refractories by Carborundum." The address: Dept. M-119, Refractories Div., Perth Amboy, New Jersey.

CARBORUNDUM

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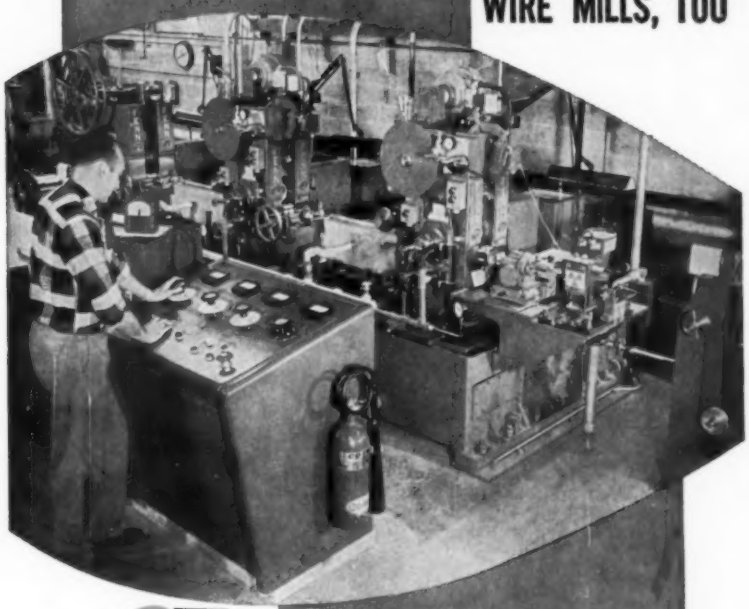
FENN

Sets the Pace

WITH PRECISION TANDEM COPPER WIRE MILLS, TOO



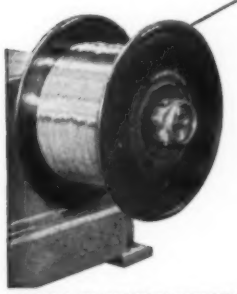
FROM .129

TO .324 .0159

AT 1,000 FPM
IN ONE PASS

to these precision tolerances

- ± .0005" on width
- ± .00005" on thickness
- ± .001" on radii of edges

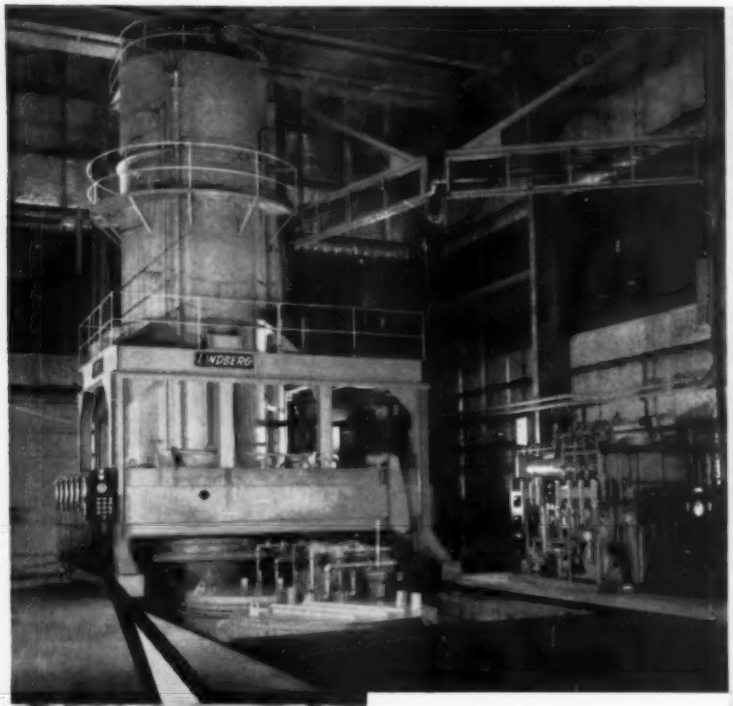


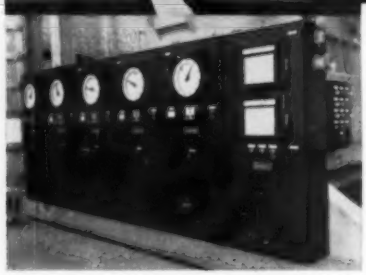
This Fenn line exemplifies the finest in high speed precision wire flattening. It was engineered and built by Fenn to produce from an entry round thin copper tape with critical dimensions at continuous production speeds in excess of 900 fpm. The installation consists of a Fenn Model 082 three stand tandem mill with separate DC variable speed drives. Each stand has carbide shell rolls with both internal and external cooling. Between stands are Fenn No. 51 power-driven edgers and coolant troughs. Exit tape is automatically gaged by electro-limit width gage and Beta Ray thickness gage. Tension and speed synchronization are regulated by dancer roll controls between stands, and at exit and to synchronize the take-up reel which must traverse wind the tape with great precision for the next operation.

Fenn engineers welcome the opportunity to design and build precision mills and related material handling accessories and instrumentation to your exact product requirements. Fenn Wire Flattening Lines are production tested and proven. They incorporate advanced engineering features and versatility found in no other rolling mills. Fenn users enjoy the competitive advantages of greater production resulting from higher rolling speeds, and closer tolerances. Comprehensive catalog will be sent upon request.

FENN MANUFACTURING CO. • 506 Fenn Road, Newngton, Conn.

Wheelco Instrumentation Provides 5-Zone Control on Advanced-Design Furnace





New Lindberg Gantry-Type atmosphere hardening furnace handles missile and aircraft parts up to 24 ft long and 6 ft 8 in. diameter.

Complete Wheelco instrumentation includes five indicating controllers with 3-function control and two multipoint recorders.

Newest ideas in furnace design and instrumentation are skillfully blended on this atmosphere-controlled, bottom quench, gantry-type furnace designed to handle tomorrow's metals as well as meeting today's missile and aircraft needs. It was built by Lindberg Engineering Company for the Lindberg Steel Treating Company.

Furnace is heated electrically, has 5 control zones, and operates between 250°F and 2050°F. Temperatures are controlled to ultra-precise limits by five Wheelco Model 3000 indicator-controllers each provided with the MMC three-function control with magnetic modulation. These instruments, coupled with magnetic amplifiers and saturable core reactors, provide precise stepless control over the entire temperature range.

For more details on the new Wheelco Model 3000 instrument write today for Bulletin F-8939.

BARBER-COLMAN COMPANY

Dept. W, 1518 Rock Street, Rockford, Illinois, U.S.A.

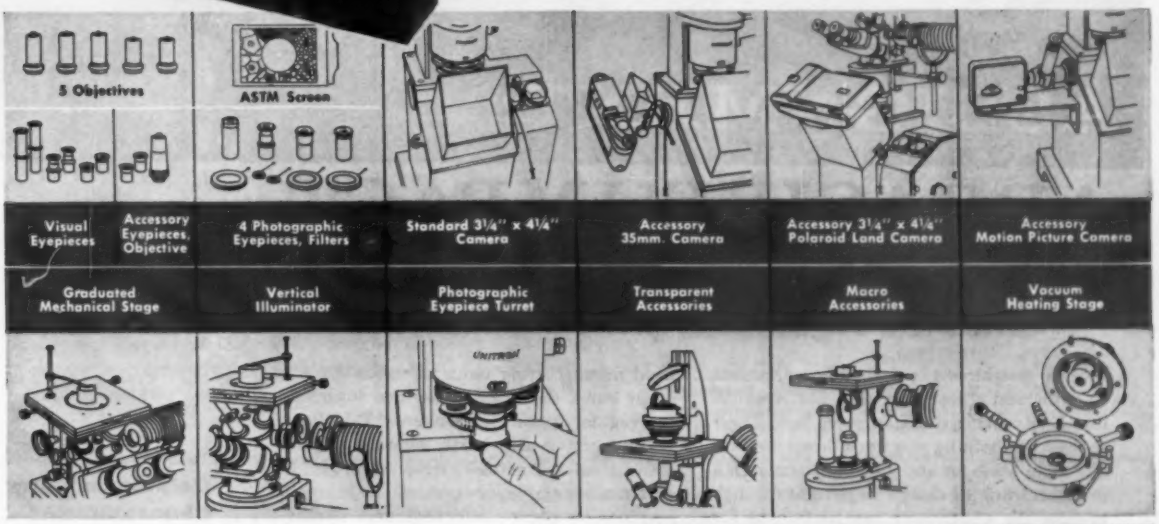
In METALLOGRAPHS...

the trend is to UNITRON!

What do you look for when choosing a metallograph? All of the popular makes are precision instruments, are reasonably versatile and, to a varying degree, are easy to operate. But, except for UNITRON, all have the bulk of an office desk or optical bench and are tagged with a price that puts a substantial dent in the laboratory budget. UNITRON, and only UNITRON, offers a completely equipped metallograph in a compact and self-contained unit, taking only 9" x 12" of table space, which duplicates the performance of large cumbersome instruments — and at a price which is hardly more than the usual cost of a conventional metallurgical microscope.

Unlike the case with most metallographs, an adding machine is not required to compute its cost. Coated optics supplied as standard equipment include 5 objectives, 4 photographic eyepieces and 3 pairs of visual eyepieces. These give a magnification range of 25X-2000X. Also included in the purchase price are the built-in 3¼" x 4¼" camera and viewing screen; high-intensity illuminator for vertical, oblique, and transmitted light; variable transformer with both voltmeter and ammeter; accessories for transparent specimens; polarizing apparatus; filters; film holders; stage clips; cabinets etc. Optional extra accessories include Polaroid Land, 35mm. and movie camera attachments; low power (5X-40X) objectives for macro work; vacuum heating stage for temperatures to 1100°C and long working-distance 40X objective; ASTM Austenite grain size viewing screen and eyepieces; filar micrometer eyepiece; and additional optics.

Such a combination of features, versatility, convenience, and value is indeed unique with UNITRON. Little wonder then, that more and more laboratories are choosing UNITRON . . . from the large organization adding another metallograph to its equipment, to the small company buying an instrument for the first time.



FREE 10 DAY TRIAL

UNITRON's Metallograph and Universal Camera Microscope Model BU-11 with binocular eyepiece; objectives: M5X, M10X, M40X, 40X for transmitted light, 100X oil immersion; paired visual eyepieces: R5X, Ke10X Micrometer, Ke15X; photo eyepieces: 10X, 15X, 20X, Micrometer; etc., as described above.

$1379 f.o.b. Boston

Monocular Model U-11 **$1195**

UNITRON

INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
204-206 MILK STREET • BOSTON 9, MASSACHUSETTS

Please rush UNITRON's Microscope Catalog 2-W

Name_____

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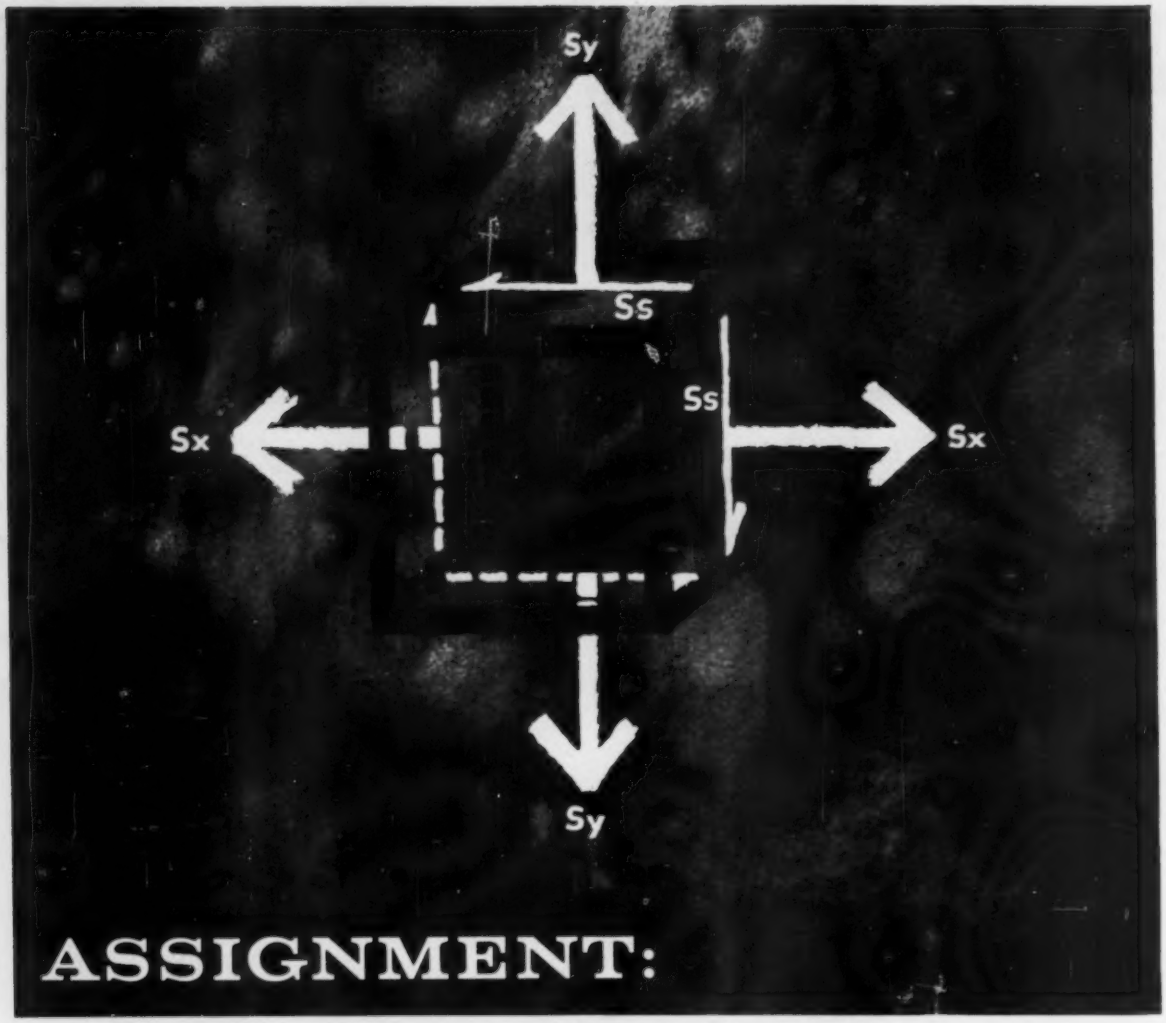
City_____ State_____

THE TREND IS TO UNITRON



ASSIGNMENT:

ABRASIVE IMPACT

How Lukens *Application Research* helps you find the right steel plate for the job

If your assignment is designing equipment to withstand abrasive impact, our Application Engineering staff can serve you. Their specialty is helping you track down the precise steel plate for any job. They research a problem from the design stage right through to how the equipment has performed for years after its installation. This practical observation and experience—combined with metallurgical know-how—is yours for the asking. It's been saving our customers money for years.

For example: working recently with a conveyor engineer, our people showed why 321 min. BHN quality Lukens "T-1" would perform equally as well as a previously used metal costing twice as much. On the other hand, the same group has suggested the regular quality of Lukens "T-1" for a uranium mine skip hoist, where a slightly softer steel will actually hold up longer. In still another conveyor application—in a coal preparation plant—our engineers demonstrated how stainless steel, Type 304, would produce long-term savings. The high initial cost of stainless was reduced by using it in Lukens clad plate form.

If your assignment is abrasive impact, why not let it be our assignment, too? Contact Manager, Application Engineering, F119 Services Building, Lukens Steel Company, Coatesville, Pa. Also ....

ASK FOR LUKENS "T-1" STEEL BULLETIN

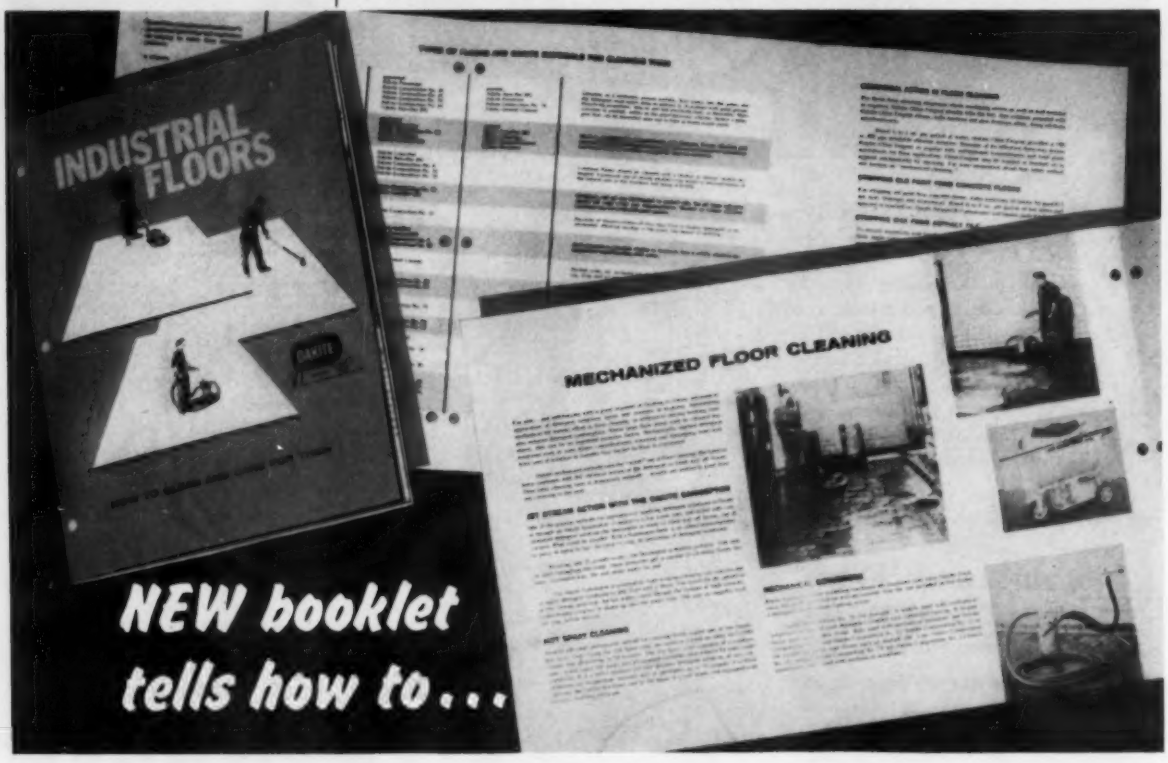
Helping Industry Choose Steels That Fit The Job

LUKENS

For the best in floor maintenance cleaning

ask Oakite

OVER 50 YEARS CLEANING EXPERIENCE • OVER 250 FIELD SERVICE MEN • OVER 160 MATERIALS



KEEP FLOORS CLEANER . . . SAFER with a PLANNED MAINTENANCE PROGRAM

Detailed 10-page booklet describes latest maintenance methods and materials for safe, efficient cleaning of twelve different types of factory floors. Included: wood, concrete, tile, and metal floorings. Following these recommended procedures assures minimum floor wear, maximum cleanliness and greatest safety.

In addition, the booklet discusses *mechanized* methods of floor care, and the remarkable savings they make possible in hours, effort and expense. Ask the Oakite man about "good housekeeping" for the plant. Meanwhile, send for your copy of *Industrial Floors: How to clean and care for them* today. Write Oakite Products, Inc., 26 Rector Street, New York 6, N. Y.

it PAYS to ask Oakite

OAKITE

50 1909-1959 SCIENCE

years' leadership in industrial cleaning

New, high-tensile steels require special care when welding.

Submerged arc welding gives the most reliable performance with T-1, but . . . fully automatic equipment is often impractical for one-of-a-kind jobs like fabrication of a 28 cu. yd. bucket.

That's why Peabody Coal Company used a "Mechanized Squirt Welder" and Lincoln alloy fluxes.

The ML-3 lets the operator guide the automatic welder by hand. Alloy fluxes, specially mixed for welding T-1 steel, provide exact metallurgical control of weld properties.

Mechanized "Squirt" simplifies T-1 steel fabrication...

RESULT: Peabody Coal Company welded the T-1 steel at speeds up to four-times faster than manually. These welds made with special Lincoln alloy flux and L-61 electrode were perfect in every respect.

For complete details on the ML-3 and alloy fluxes write to:

LINCOLN ...USA

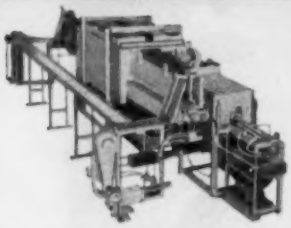
THE LINCOLN ELECTRIC COMPANY
Dept. 1303 • Cleveland 17, Ohio

world's leading manufacturer of arc welders and electrodes, ac motors and battery chargers

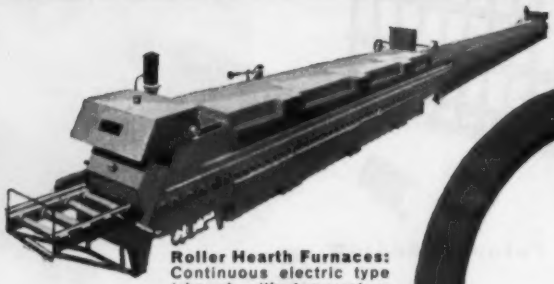
Wherever industry needs heat . . .

Wherever industry needs heat...

You'll find *LINDBERG* equipment just right for the specific job

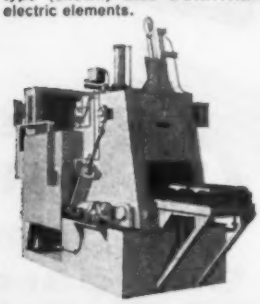


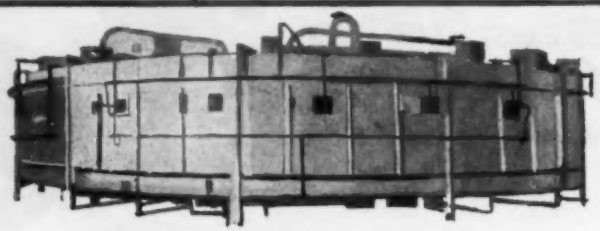
Ceramic Kilns: Fully automatic, atmosphere controlled kiln (shown) has 5 control zones for flexibility. Maximum temperature, 2700° F.



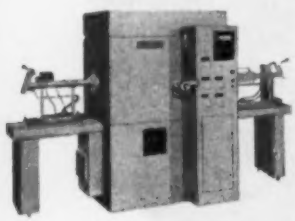
Roller Hearth Furnaces: Continuous electric type (shown) with temperature range 1300° to 2100° F.

Automatic Carbonitriding Furnaces: Automated integral quench type (shown) with CORRTHERM electric elements.



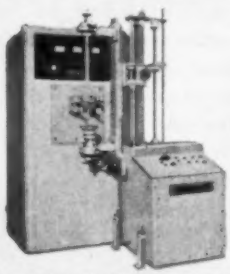


Rotary Hearth Furnaces: Doughnut type field-installed gas-fired furnace (shown) with capacity of 13,000 lbs. per hour.

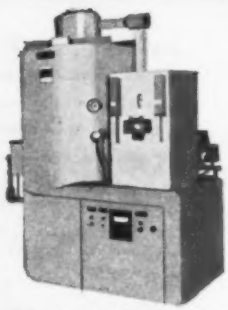


High Temperature Furnaces: New Graphite Tube Furnace (shown) with temperature range 2600° F. to 5000° F. for research and production in metal and ceramic fields.

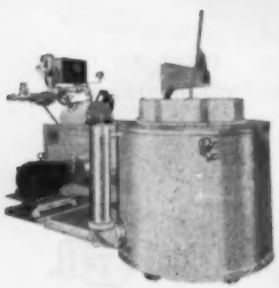
Vertical Type Furnaces: Carburizing and hardening furnace (shown) with CORRTHERM electrical heating elements.



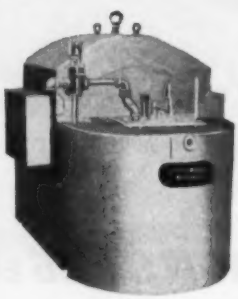
Induction Heating Units: New Lindberg Floating Zone Scanner for precise production of hyperpure semi-conductor materials and metals and Induction Heating Unit (shown).



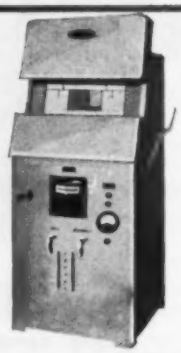
Atmosphere Generators: Hyen generator (shown) for endothermic atmospheres. Generators for all required atmospheres.



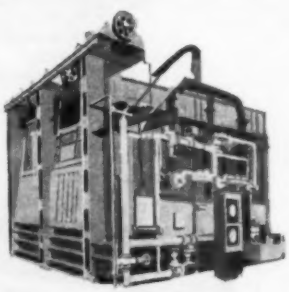
Cyclone Tempering Furnaces: Batch type fuel fired tempering furnace (shown). Famous in metal treating industry for years.



Melting and Holding Furnaces: Electric resistance furnace (shown) with capacities of 750 lbs. to 1500 lbs.



Laboratory Equipment: One-unit box furnace (shown), muffle or for non-oxidizing atmosphere with temperature range to 3000° F.



Aluminum Reverberatory Furnaces: Twin-chamber melting and holding furnace (shown) with 45,000 lbs. capacity.

Charles Hewitt, President of Dayton, says, "The Lindberg installation has kept our production at a consistently high quality level."

Work loads are positioned manually, but entire furnace operation is fully automatic.

Lindberg Carbotrol unit automatically controls and records "dew point" and heating cycles of endothermic atmosphere.

Lindberg's "dimple" vertical radiant tubes give remarkably trouble-free service and function at all times at full efficiency.

Unique Installation Cuts Heat Treating Costs and Improves Quality at Dayton

Here is a remarkable set-up for general heat treating now in operation at Dayton Forging & Heat Treating Company, Dayton, Ohio. Two integral quench atmosphere furnaces, largest of this type ever built by Lindberg, and one atmosphere tempering furnace in a "three-in-a-row" arrangement that simplifies transfer operation. Combined with Lindberg Carbotrol and Hyen generator, the entire furnace operation is completely automatic, including atmosphere control and recording. Planned by Dayton and Lindberg engineers, the installation runs around the clock, six days a week, reducing costs and producing cleaner end products, brighter job finish, freedom from "decarb" and a consistently higher quality of work.

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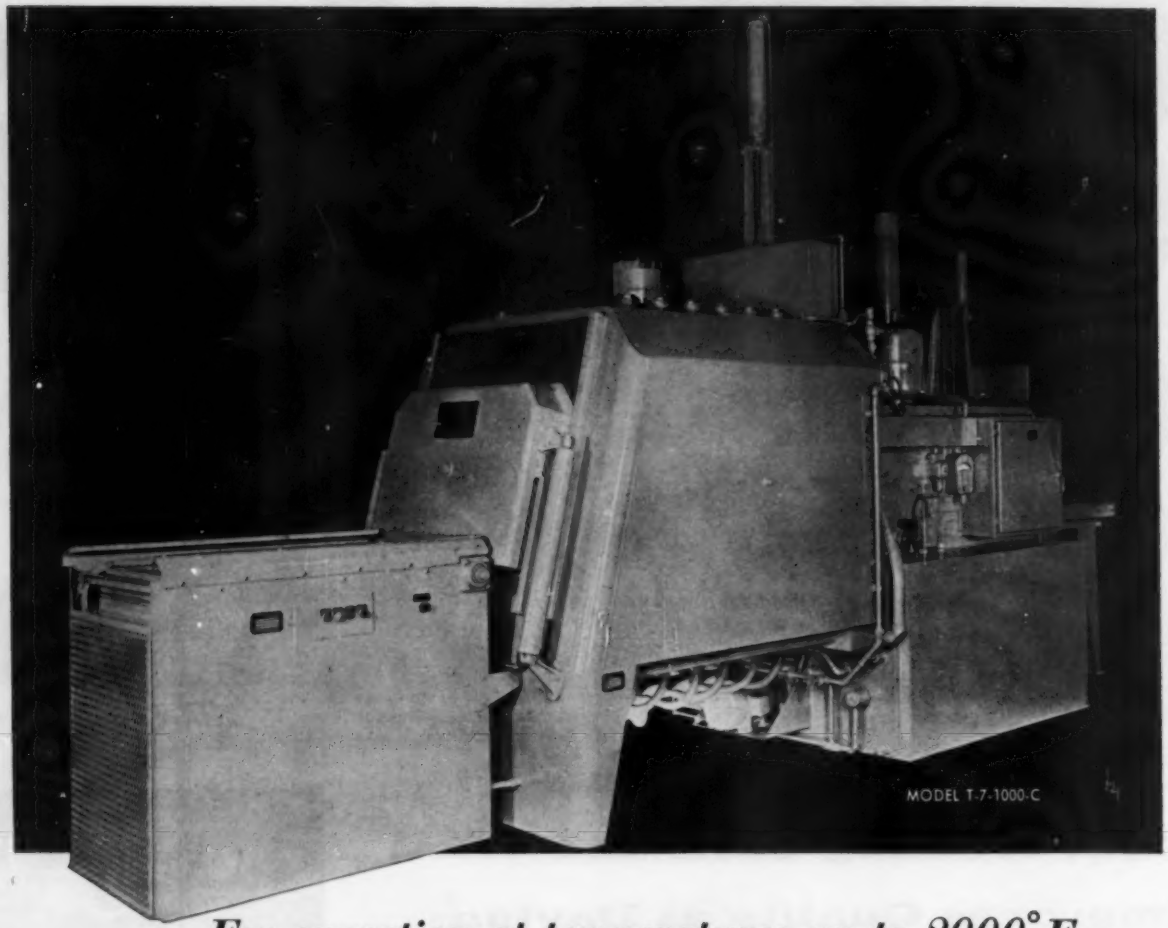

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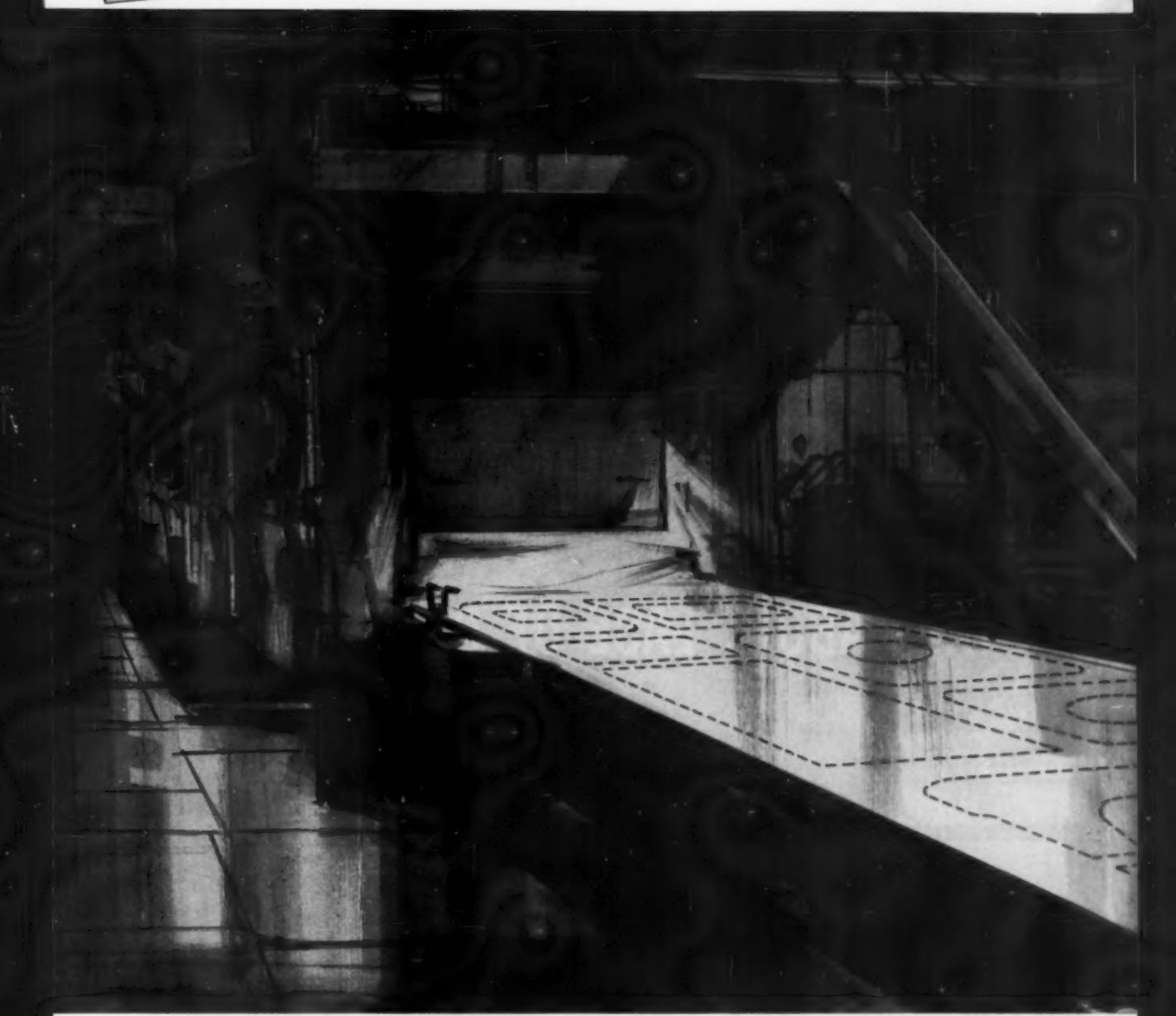

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Tool Steel Topics

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BETHLEHEM TOOL STEEL ENGINEER SAYS:

Stainless Is Tough On Tools

Many items formerly made of soft steel are now being made of stainless steel. The austenitic stainless steels (AISI 300 series) are popular because of their corrosion-resistance, plus their strength and oxidation-resistance at moderately high temperatures.

Whenever stainless parts are made with tools formerly used on soft steel, there is a marked decrease of production of parts per tool. For example, on a simple blanking operation on stainless steel, the production per grind on the punch and die usually is about one quarter of the production on soft steel.

Though it is rarely possible to change conditions so that the "normal" tool life can be realized when making stainless parts, some improvements can be made. For example, if the blanking tools were originally made of AISI W1 water-hardening or O1 oil-hardening tool steels, a change to D2 high-carbon, high-chromium tool steel is suggested. This change will improve the tool life from two to three times. Or if D2 high-carbon, high-chromium tool steel is already being used, it may be necessary to carburize, or to nitride, in order to improve the wear-resistance. Close attention must be paid to mechanical conditions, such as proper clearance between punch and die, proper penetration of the punch, and optimum grinding procedures in finishing the tools.

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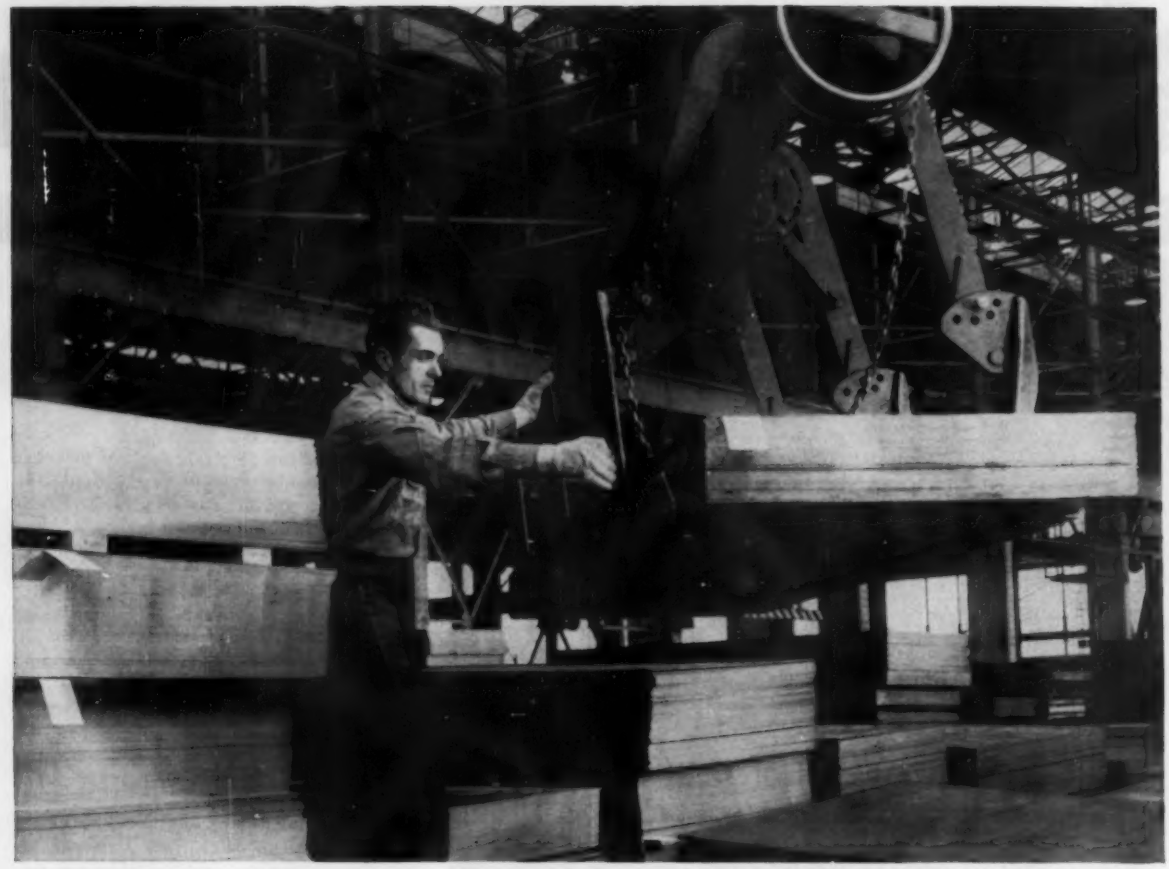

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Producing for the Supersonic Age

Metals and Fabrication Methods Used for the Atlas

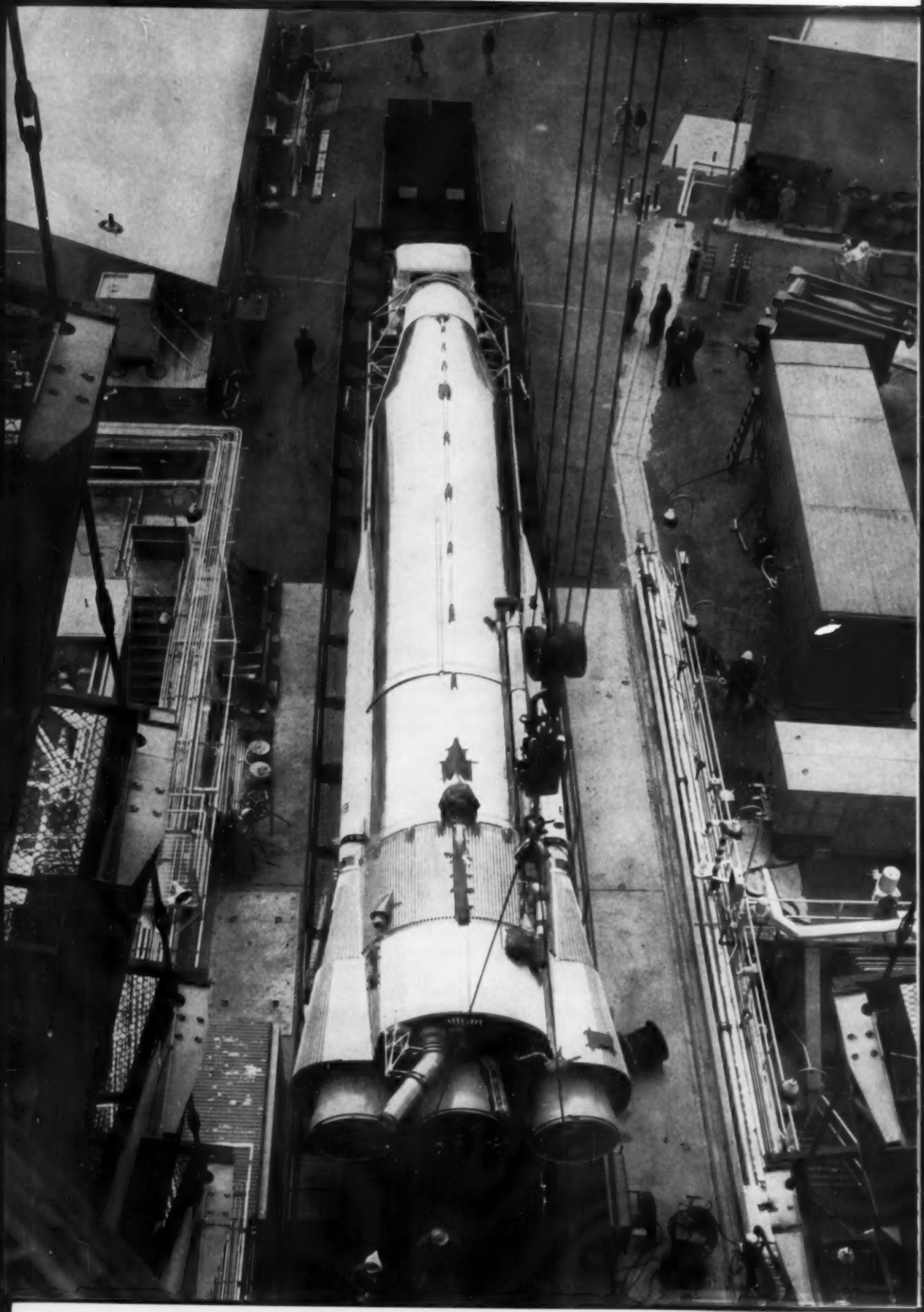
*By ABRAHAM HURLICH**

A welded structure of light-gage stainless forms the main body of the Atlas – America's first intercontinental ballistic missile. (See cover.) From the propulsion section to the nose cone, tanks some 60 ft. long and 10 ft. in diameter with no internal framework form the complete airframe. Revealed here for the first time are details on types of metals used and the precision techniques employed in fabrication. (T24e, K-general, G-general; SS, Ni-b)

UNLIKE OTHER LARGE liquid-fueled missiles which have structurally rigid propellant tanks with stiffening elements, the Air Force's Atlas represents a radical departure from conventional design in that the propellant tanks are thin-skinned with no supporting structure inside them and are kept rigid by internal pressurization. This approach has led to absolutely minimum weight designs for liquid propellant missile tanks. By suitable selection of internal pressure levels, rigid, very thin-walled tanks can be constructed, capable of carrying heavy loads. There is no danger of buckling the thin tank walls since they are subjected only to net tensile stresses resulting from internal pressurization.

Because of the lightweight tanks made possible by internal pressurization, a "one and one-half stage" missile represents an efficient design for a long-range missile. The "one-half stage" consists of a booster stage whose engines are supplied with propellants from the missile tanks. When the booster is disengaged, valves shut off the propellant flow to the booster engines, while propellants continue to feed to the main or "sustainer" engine which accelerates the lightened missile along its course. Conventional multi-stage missiles have separate sets of propellant tanks for each stage. This requires duplication of engines, adds pumping systems for propellants, and other components since each stage is a completely independent missile.

*Supervisor, Materials Research Group, Convair-Astronautics Div., General Dynamics Corp., San Diego, Calif.



While conventional engineering structures are designed with safety factors of two to five, the stringent penalties on performance imposed by weight are such that design allowables up to 90% of yield strength are employed in long-range ballistic missiles. This low safety margin means that missile materials must be thoroughly evaluated for reliability under the environmental conditions encountered during testing and flight.

Propellant Tanks

Inasmuch as welding is the only way to achieve liquid-tight joints in thin sheet metal, weldability is a prime requirement for the skin material for tanks. Also, to minimize weight and to effectively utilize high-strength metals, substantially 100% tensile efficiency must be realized in weld joints. The propellants used in the Atlas consist of a hydrocarbon fuel and liquid oxygen. The tank for the latter must be fabricated from a material which retains high ductility and resistance to brittle fracture at temperatures down to –300° F., both in base metal and weld joints.

The liquid oxygen tank is forward of the fuel tank, and its forward surfaces are subjected to aerodynamic heating as the missile accelerates out of the atmosphere. Moderately elevated temperatures are reached in the portion of the tank above the liquid oxygen level. Again, in the interest of weight minimization, the tank skin must retain high strength at moderately elevated temperatures since stresses in the skin remain substantially constant throughout flight because of internal pressurization.

Material Requirements

The skin material must also be formable for shaping of bulkheads, propellant lines, and attachments. It must be corrosion resistant to withstand long-term storage, contact with fuel and other liquids, and exposure to corrosive environments. The requirements of high strength, weldability, retention of high strength and ductility over the range from extreme subzero to moderately elevated temperatures, and the need for formability and corrosion resistance – all combined – severely restrict the types of materials for tank skins.

The class of materials which best combines these characteristics is the cold worked stainless steels. A.I.S.I. Type 301, cold rolled about 60% for a minimum tensile strength of 200,000 psi. and minimum yield strength of 160,00 psi., is used for the Atlas tanks. The sheet, about a yard in width, is cold rolled in a Sendzimir mill, giving a smooth, mirror-like finish and thickness variations of some one half to one third of A.I.S.I. standard tolerances. Thickness of the sheet must be very precisely controlled since a variation in gage of a few thousandths of an inch will significantly alter the weight of a structure containing many hundreds of square feet of sheet metal.

Start of Fabrication

Incoming sheet material is first laid out on inspection tables and carefully examined for gage, surface finish, flatness, camber, and freedom from defects. The sheet is then coiled around a mandrel, as shown in Fig. 1, and cut to form a segment of the Atlas tank. The ends of each segment are butt welded together in the heliarc welder shown in Fig. 2. This welder, which was developed by engineers at Convair-Astronautics, uses sets of hold-down levers actuated by inflated fire hoses to hold the sheet firmly together on either side of the butt weld during welding and during the postwelding cooling period to avoid hot tearing. Butt welds have been successfully made in this welder in stainless steel sheet from 0.005 to 0.050 in. thick.

The butt welded joint is then roll-planished between two hardened steel rolls to flatten the weld crowns down to the original level of the stainless sheet. A reinforcing strip several inches wide of the same material and gage as the skin segment is resistance spot welded over the inner surface of the butt welded joint. This strip is needed because the butt welded joint has an essentially annealed austenitic microstructure of reduced strength, compared to the cold worked base metal. The reinforced joint matches the tensile strength of the base metal and permits full advantage to be taken of the strength of the cold worked steel.

After each tank segment is completed, it is fitted inside large supporting rings and held in place by internal circular U-channels in which is placed a length of fire hose subsequently inflated with water to stretch the segment tautly between the inner and outer rings as shown in Fig. 3. Adjacent tank segments are slightly overlapped and roll seam welded to make a leaktight joint. Adequate strength along the missile's longitudinal axis is provided by the roll seam weld reinforced by rows of spot welds on each side of the

Atlas Missile Ready for Transport. Stainless steel tanks and bulkheads make up the upper portion of the missile, and the thrust structure, including engines and nacelles, occupies the lower third

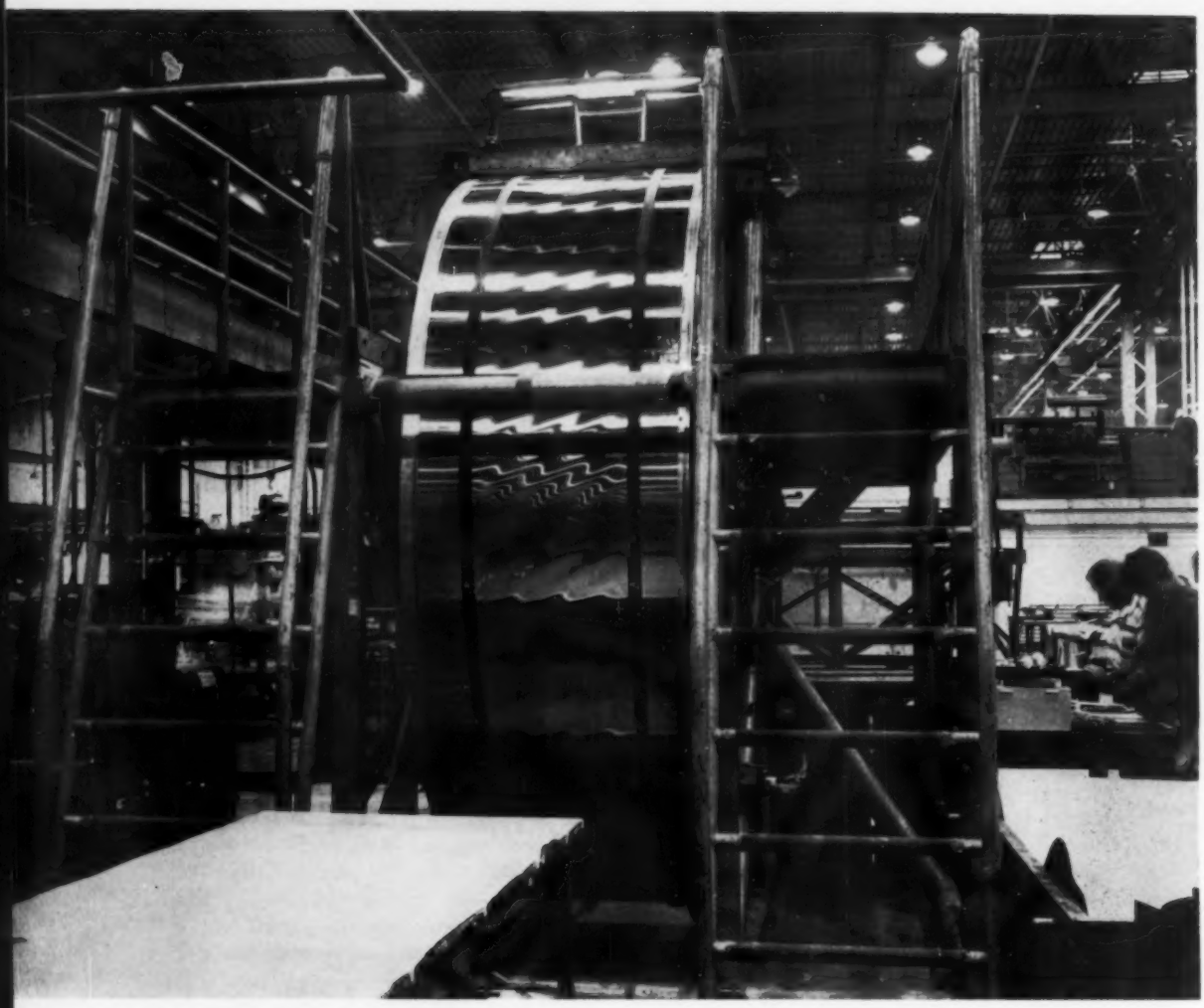


Fig. 1 — Type 301 Stainless Sheet Is Coiled Around a Mandrel, Then Cut to Form a Segment of the Atlas Tank. Inspection table is shown in foreground. The heaviest gage is less than 0.040 in. thick

seam weld. Successive segments are similarly attached to build up the entire tank structure.

Bulkheads Are Stretch Formed

Bulkheads are fabricated from stretch-formed and welded segments of cold rolled Type 301 stainless sheet, ½ and ¾ hard. These segments, or gores, are heliarc butt welded in contour welders, such as shown in Fig. 4. The welds in the bulkheads are also reinforced with doublers, spot welded to their inside surfaces along the weld joints.

The aft bulkhead is fabricated in two subassemblies, a stretch-formed curved section which blends into the sidewalls of the fuel tank (see background of Fig. 5), and a conical section, shown in the foreground of Fig. 5.

This component contains the only stiffening structure found in the missile tank assembly. The sustainer engine's thrust is fed into the conical section of the aft bulkhead, requiring structural stiffeners in this area.

Procedure for Assembly

The missile tanks are assembled and bulkheads welded into place on long beds which permit the entire assembly to rotate alongside the welding machines, as shown in Fig. 6. During this stage of manufacture, large supporting rings are necessary to keep the tank skins from collapsing. Once

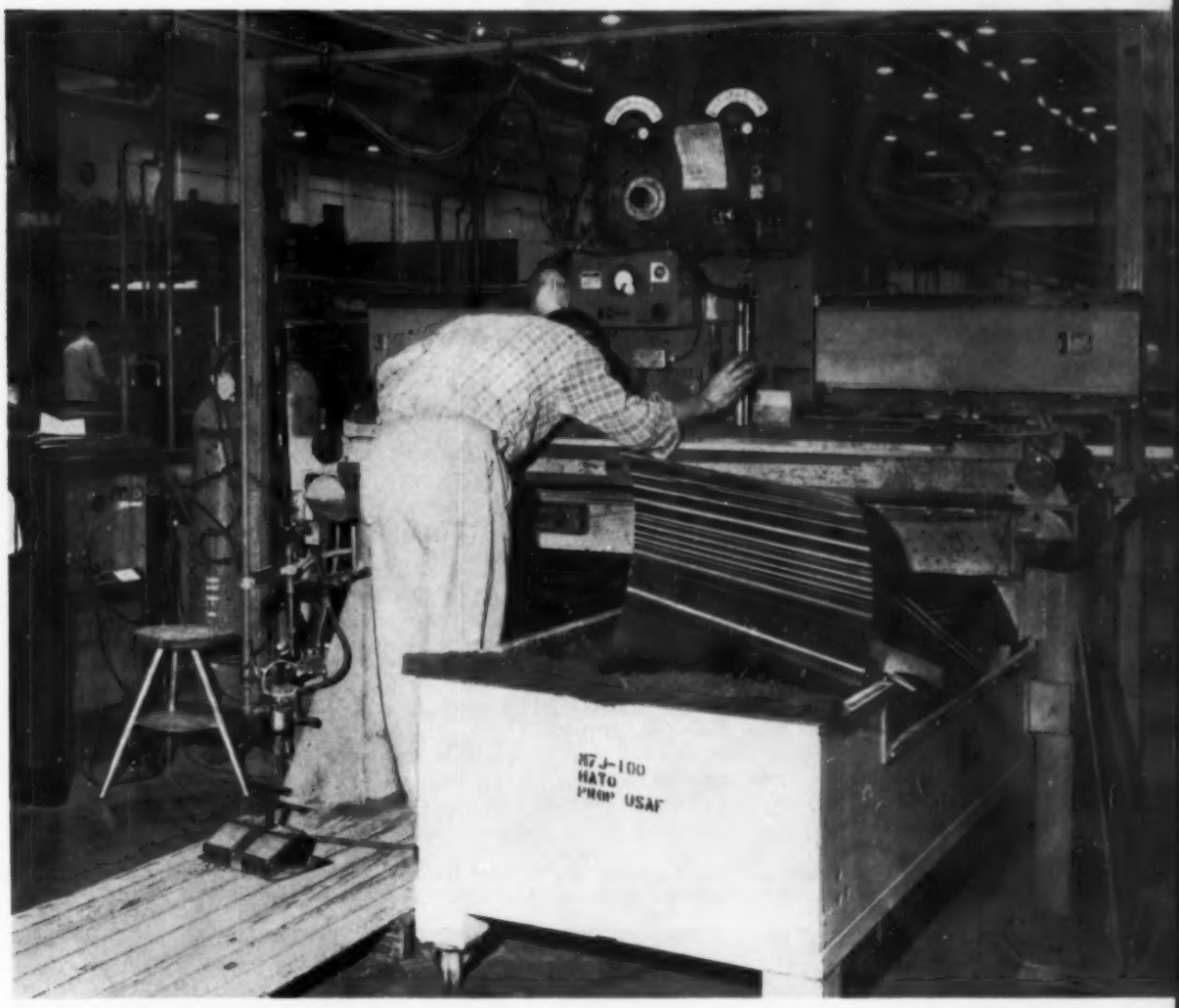


Fig. 2 – The Ends of Each Segment Are Butt Welded (Heliarc) in This Welder. Butt welds have been made in stainless sheet 0.005 to 0.050 in. thick

the tanks are completed, however, they are filled with dry nitrogen gas to a pressure of only a few pounds above atmospheric. In this condition, the tank skin is tautly stretched; the missile body becomes rigid enough to resist bending loads and can be safely handled and transported.

Thrust Structure

The thrust structure of the Atlas occupies the lower third of the missile, as shown in the photo opposite p. 67 and also by the cover photo, and consists of the booster engines (the two outer ones), engine nacelles, and a body section fabricated from 2024 and 7075 aluminum alloys. The latter represents a rather conventional aircraft fuselage structure with corrugated stiffening and other structural elements. The engine nacelles are fabricated from sandwich structure, using an aluminum core covered with fiberglass plastic laminate. This sandwich construction weighs about 1 lb. per sq.ft. of area and is sufficiently strong and heat resistant to withstand aerodynamic loads and radiant heating by the engine's exhaust flames.

The engine compartment is protected from the exhaust flames by a large shield which fits over the end of the thrust structure and has openings for the swiveling engines to fit through. This shield prevents radiant heating of the many hydraulic and electrical lines and controls that fit in the engine compartment in the space between

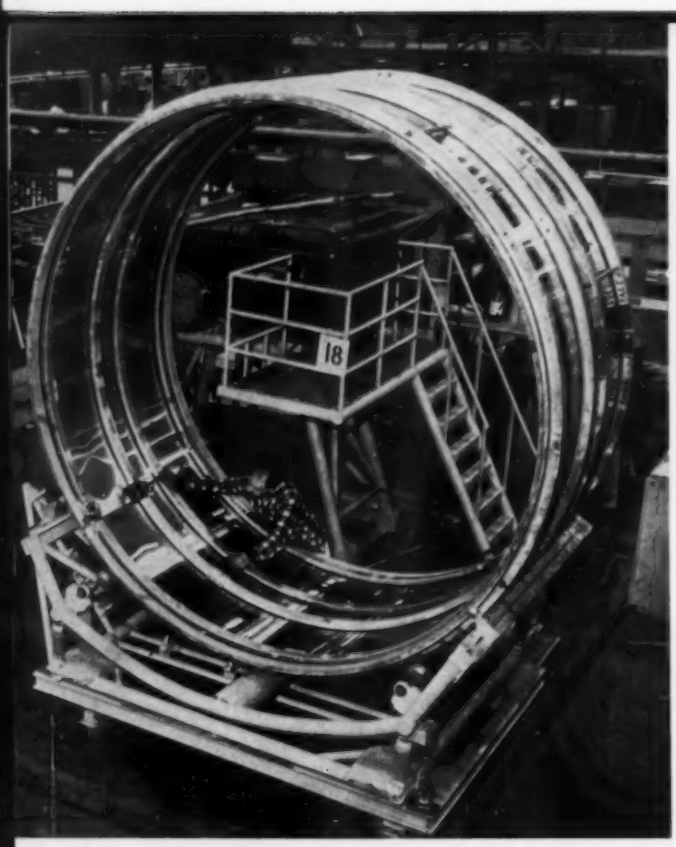


Fig. 3 – Two Overlapping Tank Segments Are Positioned for Transverse Roll Seam Welding to Make a Leak-Tight Joint. Seam weld is reinforced by rows of spot welds on each side of the seam weld. Successive segments are similarly attached to build up entire tank structure

the engines and the aft bulkhead. It is also fabricated from a sandwich structure consisting of an aluminum core covered with a plastic laminate.

High-Pressure Gas Storage Bottles

A number of high-pressure storage vessels are contained in each missile to furnish the helium gas for internal pressurization of fuel and liquid oxygen tanks as well as pressure to operate pneumatic components. In order to increase the gas storage capacity of these pressure vessels and reduce their weight to a minimum, they are surrounded with an envelope of liquid nitrogen which cools the vessels and their contents to –320° F.

The pressure vessels are spheres roughly 20 to 25 in. in diameter which are fabricated by welding together two hemispherical forged sections, fitted with bosses containing the gas inlet and outlet ports. (An article on vessels of this type appeared in the March 1959 issue of *Metal Progress*, p. 66, entitled "Fuel Containers for Rockets".)

Titanium Used for Pressure Vessels

The pressure vessels posed a critical materials problem because of the requirements for light weight, high operating stresses, extreme subzero

Fig. 4 – Bulkheads Are Fabricated by Contour Welding Stretch-Formed Segments of ½ and ¾ Hard, Type 301 Stainless. Also shown is completed bulkhead assembly

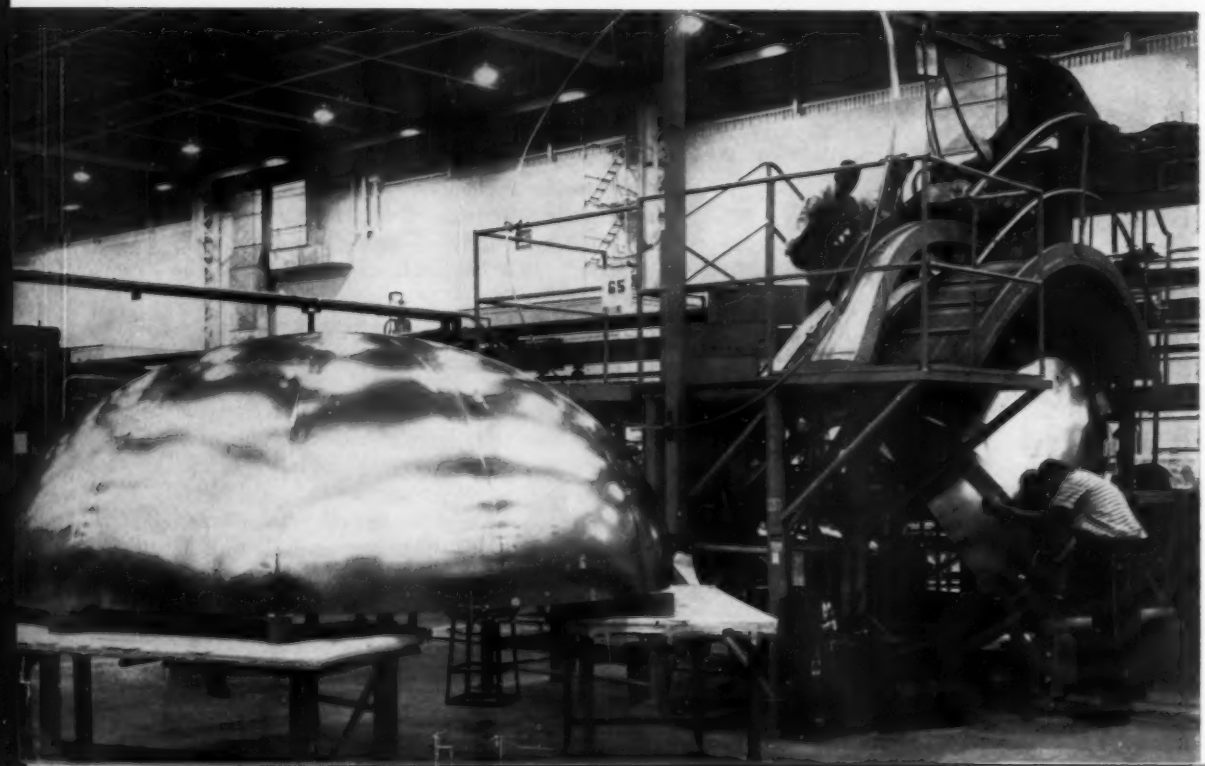


Fig. 5 – Stiffeners and Attachments Are Resistance Spot Welded to Aft Bulkhead. This bulkhead is fabricated in two subassemblies, a stretch-formed curved section which blends into the sidewalls of the fuel tank (see background) and a conical section, shown in foreground, which contains the only stiffening support structure in the missile tank assembly

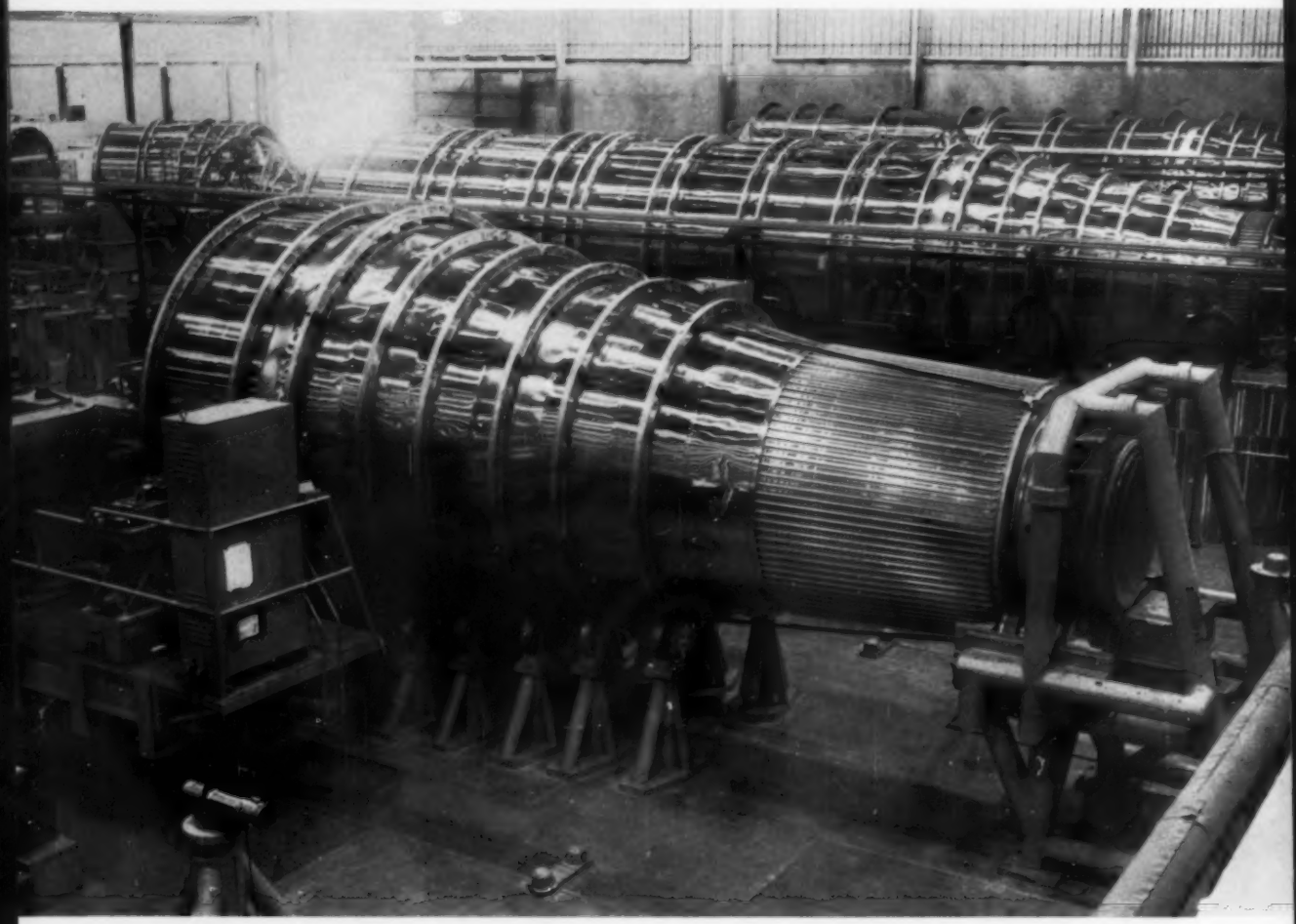


Fig. 6 – Partially Assembled Missiles Positioned for Welding Bulkheads in Place. Skin segments are still supported by temporary rings. After bulkheads are attached, the tanks are sealed, then pressurized with dry nitrogen gas and supporting rings removed. Corrugated structure forward of tank is nose adapter section

temperatures, and resistance to vibration under high pressure. The weights which were established for these components were such that, if made from steel, an alloy having a minimum yield strength of about 240,000 psi. would be needed. Alloy steels heat treated to this strength are invariably brittle at –320° F. The same is true of high-strength aluminum alloys of comparable strength-to-weight ratios. A titanium alloy – 6% Al, 4% V – was selected for this application, and pressure vessels which meet all requirements of weight and performance are being produced.

A method being used to produce these high-pressure vessels is to solution quench hemispherical forgings, finish machine the inside and outside contours, weld with either unalloyed or alloyed titanium filler metal, then age. The latter treatment also stress-relieves the circumferential weld. Typical mechanical properties obtained in titanium alloy pressure vessels fabricated in this fashion are shown below:

	Test Temperature	
	70° F.	–320° F.
Yield strength, 0.2% offset	137,000 psi.	229,000
Tensile strength	156,000 psi.	236,000
Elongation	16%	11
Reduction in area	52%	36
V-Notch Charpy impact energy*	17.5 ft-lb.	10.0

*Double-width, half-thickness specimen with one half the standard depth of notch.

Transfer Ducts for Liquid Oxygen and Fuel

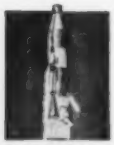
These ducts consist of rather complicated piping containing Y-joints, flanges and bellows of various diameters up to some 10 in. In view of the complicated shapes and curvatures, the material for these components must have excellent formability. In addition, good ductility and resistance to brittle crack propagation at liquid oxygen temperatures are required for components exposed to these temperatures.

The material chosen for this application was "K" Monel – a nickel-copper alloy containing aluminum as the precipitation hardening agent. This metal is extremely ductile and formable in the annealed condition and can be readily welded by the inert-gas tungsten-arc process. It can then be age hardened by heating at a moderate temperature. After aging, it has a room-temperature yield strength of 90,000 to 100,000 psi. and a high level of ductility that is retained down to –320° F. in both base metal and weld joints.

Segments of some of the fuel and liquid oxygen transfer lines are shown in Fig. 7. The elbows are formed in half sections and are flanged, the flanges being burned down during welding to form butt welds.

In some of the small lines (3 to 4 in. diameter), the thickness of the sheet material, to allow adequate stiffness and resistance to denting and bending in handling rather than to provide strength to resist stresses due to internal pressurization, becomes the controlling design consideration; hence, these lines are not designed as minimum weight components. These lines, particularly those for liquid oxygen, are made from Type 321 or 347 stainless steels. They are weldable, and do not become embrittled in weld heat-affected zones. In addition, these steels are very ductile and crack resistant at extreme subzero temperatures.

Fig. 7 – Parts of Transfer Lines for Fuel and Liquid Oxygen Are Fabricated From "K" Monel. Elbows are formed in half sections and are flanged. Flanges are burned down during welding to form butt welds



Producing for the Supersonic Age

Solid-Fuel Rocket Chambers for Operation at 240,000 Psi. and Above—I

*By M. E. SHANK, C. E. SPAETH, V. W. COOKE and J. E. COYNE**

New ideas in design and fabrication were applied in building solid-fuel rocket cases to withstand 240,000-psi. tangential stresses. Built of modified H-11 toolsteel, these cases were constructed without longitudinal welds. When small test chambers performed satisfactorily, a full-scale vessel was built. Its unexpected failure during testing resulted in an intensive investigation into the effect of hydrogen. (Q26, T2p; SGA-h, TS)

ONE OF THE MOST important problems today is the construction of high-strength missile cases for solid-fuel rockets. Very high operating stresses are advantageous to maximize the useful load that the rocket will carry. This is particularly important in the later stages of multistage vehicles. For each additional pound carried in a third-stage structure of a rocket, for instance, 25 to 35 lb. of additional fuel must be placed in the earlier stages.

Up to the present time, integrity of solid-fuel rocket chambers has left something to be desired, largely because of difficulties related to details of design, techniques of fabrication and inspection, and choice and handling of materials. The situation reminds one of problems encountered in the failure of welded ships during World War II and in the failure of carbon plate steel structures before and after World War II. Such failures were almost always traceable to similar causes. Because of the very much higher stresses encountered in rocket chambers, all of the difficulties of the previous situation are magnified.

This report describes the production and testing of full-scale solid rocket casings about 40 in. in diameter at stress levels of 240,000 psi. The pilot test program leading up to this successful operation, with its attendant successes and disappointments, is also described in detail. Figure 1 shows the finished vessel and component parts. It is about 6 ft. long and 40 in. in diameter. Nominal wall thickness of the cylindrical portion is about 0.070 in.

*Dr. Shank is associate professor of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass. The other authors are associated with Pratt & Whitney Aircraft. Mr. Spaeth is design engineer, Mr. Cooke is supervisor, Materials Development Laboratory, and Mr. Coyne is project metallurgist, Materials Development Laboratory. This is the first article in a series of two.

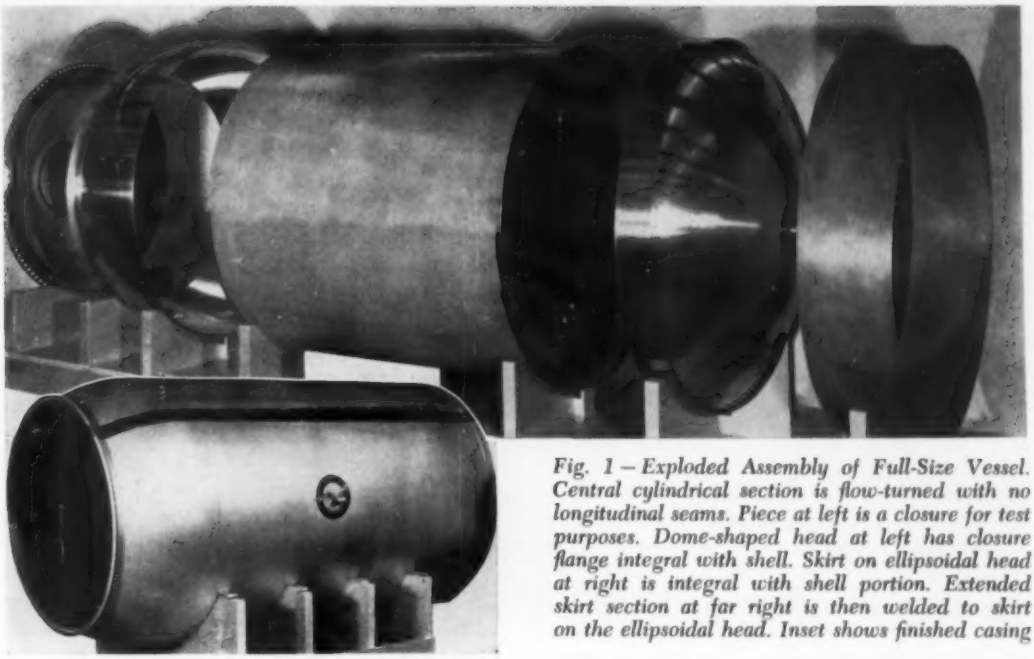


Fig. 1 – Exploded Assembly of Full-Size Vessel. Central cylindrical section is flow-turned with no longitudinal seams. Piece at left is a closure for test purposes. Dome-shaped head at left has closure flange integral with shell. Skirt on ellipsoidal head at right is integral with shell portion. Extended skirt section at far right is then welded to skirt on the ellipsoidal head. Inset shows finished casing

At this point, it might be well to review in greater detail some of the difficulties being encountered by some segments of the missile industry in the design and fabrication of solid-fuel rocket chambers. Currently, the majority of rocket chambers are rolled and welded cylinders, capped by heads of an ellipsoidal shape. Separate bosses, made of individual forgings, are welded to openings in the heads to provide mountings for igniters and nozzles. The heads are then connected to the cylinders by circumferential butt welds. Since connections are needed to provide for mechanical connection of one stage to the next, light skirts are welded on to the vessels in the vicinity of the heads. Sometimes these skirts, as well as certain attachment brackets, may be welded to the chamber after heat treating the casing.

According to reports of those who have investigated failures, it seems that neither the local heating employed for welding after heat treating nor the tempering itself eliminates patterns of residual stress of substantial magnitude in these casings. In addition, bending stresses are developed in the regions surrounding welded-in skirted bosses. These bending stresses can be rather high. Some sinking or tilting of boss reinforcements of the ports is difficult to avoid, and attachments made by welding after heat treatment are apt to result in cracks which escape detection

In this comprehensive two-part report, the authors come to four significant conclusions:

1. The manufacture of solid-fuel rocket casings to operate at 240,000 psi. tangential stress is practical and feasible as demonstrated by cyclic tests on 6-ft. long vessels, 40 in. in diameter. Stress levels up to 260,000 appear possible if plastic strains of about 1.5% can be tolerated.

2. Vacuum-melted steel, virtually without inclusions, is a necessity for high-performance casings.

3. In designing with present-day alloys, notch strength ratios of less than 1.0 must be used to get minimum feasible weight. This requires the best quality in design, fabrication and materials.

4. When water is used for hydrostatic testing, electrolytic action can cause hydrogen embrittlement in the parent metal. Delayed failure may result.

The authors also observed that critical crack length for the H-11 material used in this investigation was 0.010 in. in the stress range of interest, 240,000 psi. Other unusual items in this article include the information that deliberate decarburization of 0.005 in. prevents surface cracks from spreading.

because they are covered by a tacked-on skirt or bracket. Roughness of weld contours also lends additional local stress elevation.

The material used in one program is an A.M.S. 6434 steel, which is really a modified A.I.S.I. 4130 analysis. It is usually of air-melted stock. Composition is found in practice to vary between cylinders, heads and bosses. In addition, various degrees of decarburization occur during processing. Variations from 0.32 to 0.38% C have been observed in different parts of the same chamber.

Most of the preliminary chambers have been made to yield stresses of 190,000 to 200,000 psi., with flight chambers designed to a yield stress of 205,000 to 215,000 psi. It had been hoped that yield stresses of 230,000 to 240,000 psi. could be employed. However, it has been concluded that attempts to utilize a higher yield stress must await a satisfactory solution of presently encountered fracture problems at the lower yield stress.

To summarize – the conditions which have caused fracture failures to the present time are a mixture of three things: high stress, prior cracks, and low fracture toughness. The latter property, of course, is inherent to a particular material and can be expected to decrease as the strength level increases. However, there are techniques of overcoming this inherent disadvantage.

size casing before assembly. The main longitudinal section is seamless, having been flow-turned into a cylinder from a solid seamless ring forging of the same internal diameter. The ellipsoidal head on the right of the photograph has been forged and machined. The base of the attachment skirt is integral with it. In this way, the high stress concentrations normally found when a skirt is tack welded onto an ellipsoidal head are minimized. The main portion of the attachment skirt (also flow-turned and seamless) in the far right of Fig. 1 is then welded directly to this base of the integral attachment skirt. The left-hand head in Fig. 1 is machined out of a single forging. The large flange is integral with this ellipsoidal head.

Finally, the closure at the left end, used for test purposes, is contoured in such a way that no unusual bending stresses are transmitted to the vessel during hydrostatic testing.

Following the decisions concerning the basic design criteria, considerable thought was given to the choice of material from which to manufacture it. On the basis of information concerning strength, ductility and toughness then available, as well as ease of fabrication, an H-11 composition was chosen. This material is a 5% Cr toolsteel, with 0.42% C, 0.29% Mn, 0.96% Si,

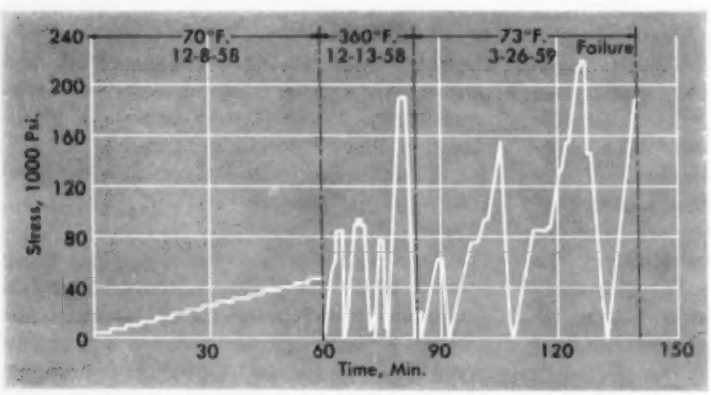


Fig. 2 – Testing Schedule of Full-Size Pressure Vessel Which Failed

In the development of the present casings, it was decided at the outset to obviate problems associated with awkward design details by eliminating such details altogether. The number of welds in the casing was minimized and it was decided that longitudinal seam welds would not be used. This insured that the tangential stresses, which are the highest stresses in casings of this type, would always be carried in solid material. Figure 1 shows the various portions of the full-

5.17% Cr, 1.35% Mo, 0.52% V. Phosphorus and sulphur were held to 0.021% and 0.006%, respectively. To get the cleanest and highest quality material possible, vacuum-melted stock was employed.

One of the major factors in picking an H-11 steel was the success achieved in a pilot series of pressure vessels 9.5 in. in diameter and about 14 in. long. Wall thicknesses in the cylindrical portion were about 0.040 in. The cylindrical

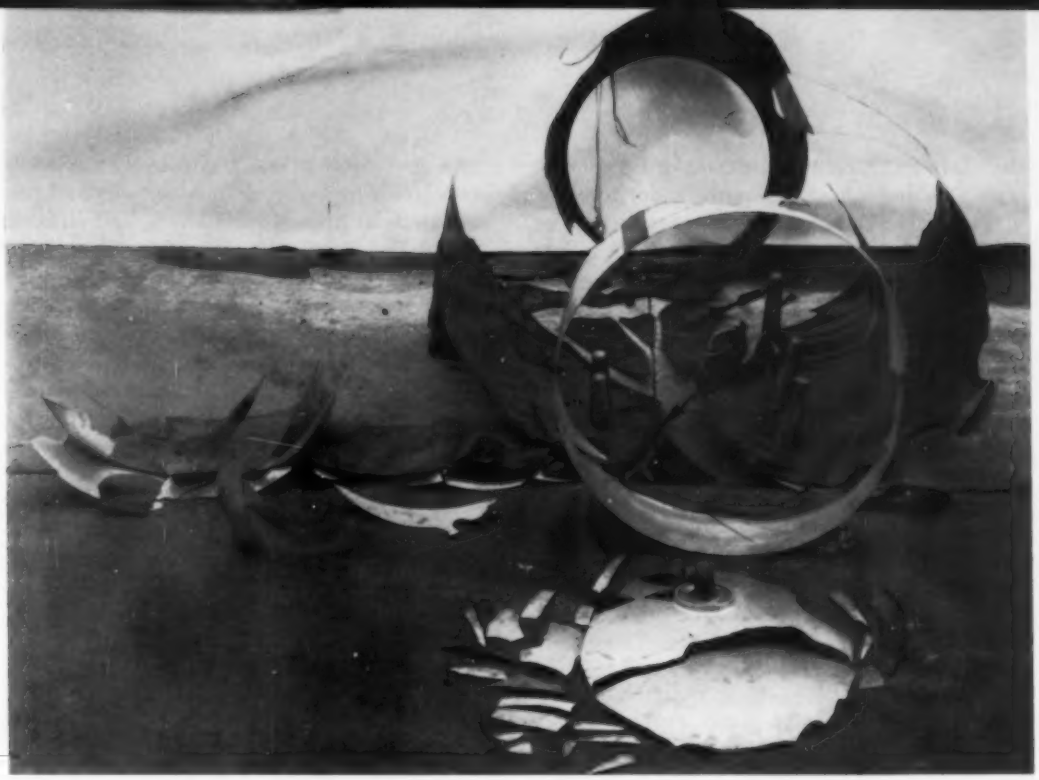


Fig. 3 – Remains of Full-Scale Missile Casing After Failure. Cylindrical objects resting on the central portion of the fractured pieces are weights used to hold them in position for photograph

portion consisted of two hydroformed sections with integral hemispherical heads. The two halves were joined by a girth weld. Failures originating at the weld were encountered in hydrostatic tests of some of the earlier test vessels. These difficulties were corrected. Of nine test vessels, in which the failure origin was a weld, four failed at stress levels of 254,700, 263,000, 226,000 and 275,000 psi., based on the tangential stress at the thinnest section. The remaining vessels failed at stress levels below 200,000 psi.

Another series of vessels failed at very high stress levels with the origins of failure in the parent metal. In one of these cases, the tangential failure stress was 308,900 psi. In another, it was 323,600 psi.

Careful attention was also paid to the details of fabrication in the full-size cases. The cylindrical section and skirt were flow-turned in three passes, with annealing in an atmosphere between passes. They were then sized, trimmed, and stress-relieved. The dome sections were stress-relieved between machining sequences. The individual parts were then fusion welded (machine) by the inert-gas shielded-arc method with parent metal filler rod. No tack welds were employed, and extremely careful fit-up was insured before the beginning of each welding operation. Following this, the entire assembly was stress-relieved in an atmosphere, then air cooled. The assembly was then inspected by fluorescent penetrant, radiographic, and magnetic particle methods. Following this, the assembly was hardened by heating in a combusted gas atmosphere to 1850° F. for 30 min. and air cooling. It was then double tempered in an air atmosphere at 1050° F. for 2 hr. and air cooled. Again the assembly was inspected by radiographic and magnetic particle methods.

It should be noted that in the course of the heat treating operation the entire surface of the vessel was deliberately decarburized to a depth of 0.003 to 0.005 in. This treatment insured a greater toughness on the surface of the material where flaws are most likely to occur, and discouraged possible spreading of such cracks into the interior of the skin.

In the final magnetic particle inspection after assembly, small protrusions were evident on the inner surface of the cylindrical section. These were located in four areas each about 1 in. in diameter. Examination of the processing history indicated that these protrusions had developed in the flow-turning operation due to imperfections on a flow-turning mandrel. This difficulty has since been eliminated. A decision was made to eliminate some of these surface

defects in the interior of the cylinder by grinding with a rubber wheel to remove about 0.005 in. of material. These ground areas later played a very important part in the subsequent failure of this particular vessel.

The vessel had been designed for a material with a yield strength level of 235,000 psi. and a tensile strength of 270,000 psi. nominal. Following manufacture, the vessel was set up on a test rig and hydrostatically tested with water at 70° F. It was tested in successive steps over a period of 1 hr. to a maximum wall stress of 46,200 psi. in a tangential direction (see Fig. 2). The water was then removed. Several days later, it was filled with glycerine which had been heated to 360° F. (At that time, a specification required hot glycerine at 360° F.) The hot glycerine contained some water which could not be eliminated. Four tests were performed, as shown in Fig. 2, the last test being at 188,000-psi. tangential wall stress for 3 min. Finally, several months later, a third series of tests was performed at room temperature, again employing water as the hydrostatic fluid. Tests were successfully performed at stress levels of 61,700, 154,000 and 216,000 psi. As the fourth test in this series was being run to reach a stress level of 220,000 psi., premature fracture occurred when the vessel had reached only 185,000 psi. This was considerably lower than the previous successful test. Catastrophic failure occurred, with the shattering results shown in Fig. 3. The water had been in the vessel 57 min. in this final test series.

An investigation was immediately started to determine why the vessel, having survived previous tests at higher stress levels, had failed at a level of 185,000 psi. tangential stress in the cylindrical portion. As a first step, the pieces were reassembled. Examination of the many feet of fracture surface showed that chevron or herringbone markings, usually found in brittle failures of carbon plate steel structures at relatively low stress levels, were present in the casing. The apices pointed back to the direction from which the failure had come. While the crack pattern was very complex, it was clear that all markings led back to a single origin of fracture, namely to the site of a protrusion on the inside of the flow-turned cylinder which had been removed by grinding. This origin is shown in Fig. 4. Figure 5 shows a complete map of the fracture paths, with the origin of failure. All of the ground areas of Fig. 4 appear to be pitted by corrosion. The pits were found to be 0.003 to 0.005 in. deep. The surrounding material shows no corrosion. Figure 6 shows the surface of fracture at the origin of failure. The origin is clearly shown as a pit in the inner cylindrical surface. Fracture markings fan out from this pit in both directions. There is a shear lip present along the edges of the fracture except at the pit. This is typical of catastrophic brittle failures at much lower stress levels and in much softer materials.

Careful metallographic examination was undertaken of the pitted area at the origin of frac-

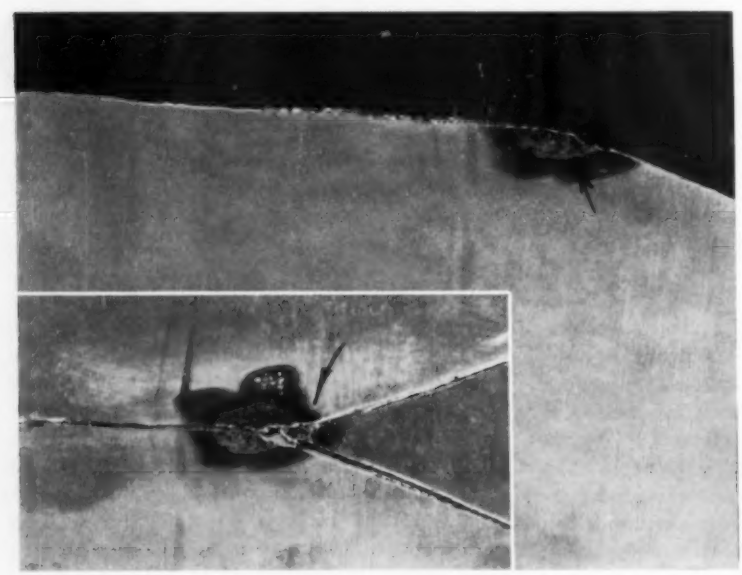


Fig. 4 — Inner Surface of Full-Scale Missile Casing After Fracture. Arrow points to origin of failure. Inset shows assembled fragments at the origin

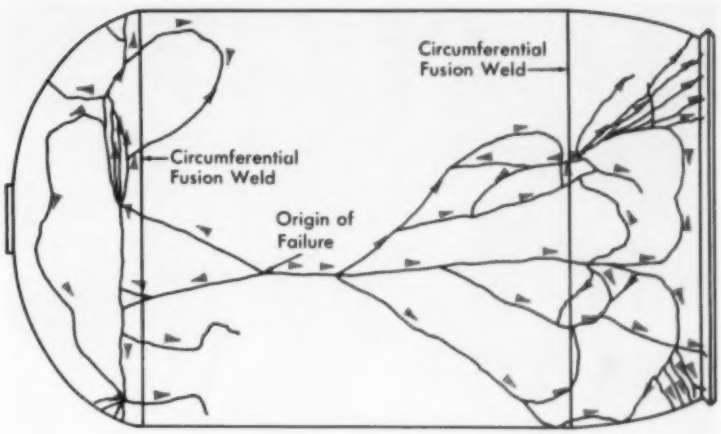
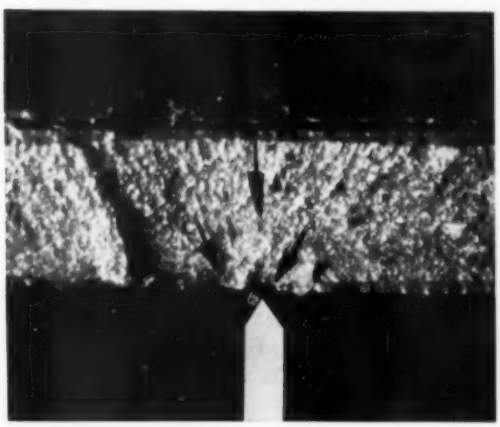


Fig. 5 — Map of Outer Surface of the Full-Scale Missile Casing, Showing Fracture Pattern as Determined From Fracture Surface Markings. Arrows indicate the direction of fracture propagation

ture, of other pitted areas not near the fracture surface, and of the original protrusions found after the flow-turning operation. It will be remembered that several of these protrusions were not ground out. Figure 7 is a photomicrograph of a typical pit at 500 diameters, parallel to the inner surface of the pressure vessel. Particularly significant are the cracks radiating from the pit. Features of these cracks will be discussed in greater detail later.

Figure 8 shows some of the features of three additional unrepaired flow-turning defects revealed (in the vessel interior surface after failure) by magnetic particle inspection. None of these defects was connected in any way with the failure. All of the defects appear to be laps or folds which became filled with oxide during the hardening operation. The lesson here is immediately obvious. Very small defects of this kind may be less dangerous when left in than when they are removed by grinding after decarburization of the surface.

Fig. 6 — Surface of Fracture at Origin in Full-Scale Rocket Casing. Failure started at inner surface of the cylindrical wall section in pitted region shown in previous figures. Note pitting at the origin of failure indicated by arrow. All fracture markings fan out from this point, and toward the right of the figure have developed into chevron markings. A shear lip is present everywhere except at exact point of origin. This origin was about 12 in. from nearest circumferential fusion weld



Standard tensile tests were performed on specimens machined from the fragments in the axial direction of the cylinder. Tensile strengths of two specimens were 273,000 and 272,000 psi. Yield strengths at 0.2% offset were 236,000 psi. and 240,000 psi. Elongations were 5% and 6% respectively. It was obvious then, that the general structure of the vessel had adequate strength to withstand hydrostatic tests of greater pressures than had been employed at or before the time of failure.

Because of the appearance of the pitted areas under the microscope, particularly the cracks radiating from the pits, and because of the relatively long time at which the pressure vessel had been kept under partial loading during the hydrostatic testing, delayed failure connected with hydrogen was suspected. The detailed effects of hydrogen will be discussed in Part II in *Metal Progress* next month. An extensive series of delayed failure tensile tests was therefore performed. Smooth and notched tensile specimens were stressed at increasing stress levels, being held 5 min. at each load until fracture occurred. Some of the smooth specimens were taken from areas in the cylinder portion of the vessel that showed no surface defects. One smooth specimen contained a flow-turning defect which had been repaired by grinding. Another smooth

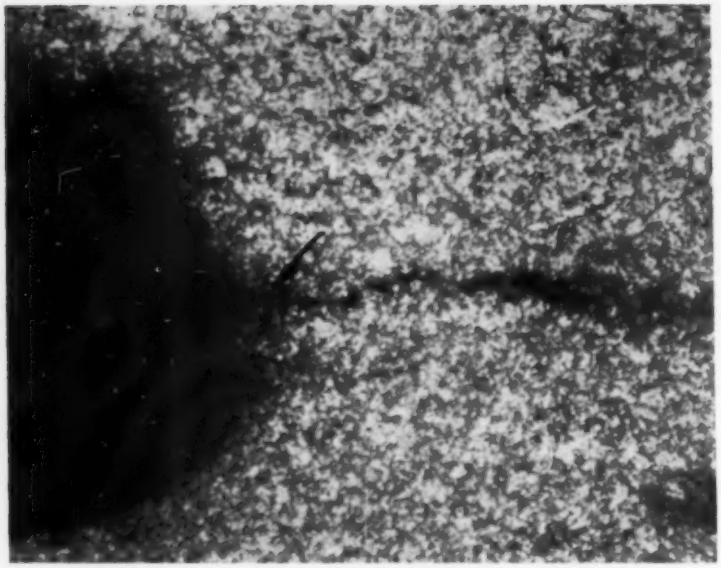


Fig. 7 – Section Parallel to Inner Surface of Full-Scale Fractured Rocket Casing. This shows the region of a pit. The entire vessel had been decarburized deliberately to a depth of 0.005 in. yet there is no decarburization along the pits or cracks. 1% nital etch. 500 ×

specimen contained a flow-turning defect which had been left in its original state as exemplified by Fig. 8. Two specimens were in the notched condition. Of the smooth specimens which were tested to failure and which contained no defects, one ruptured after 2 min. at 265,000 psi. The remainder, three specimens in all, ruptured at 274,000 psi. or higher – well above the nominal tensile strength of the material. One smooth specimen was held for 69 hr. at 240,000 psi. with

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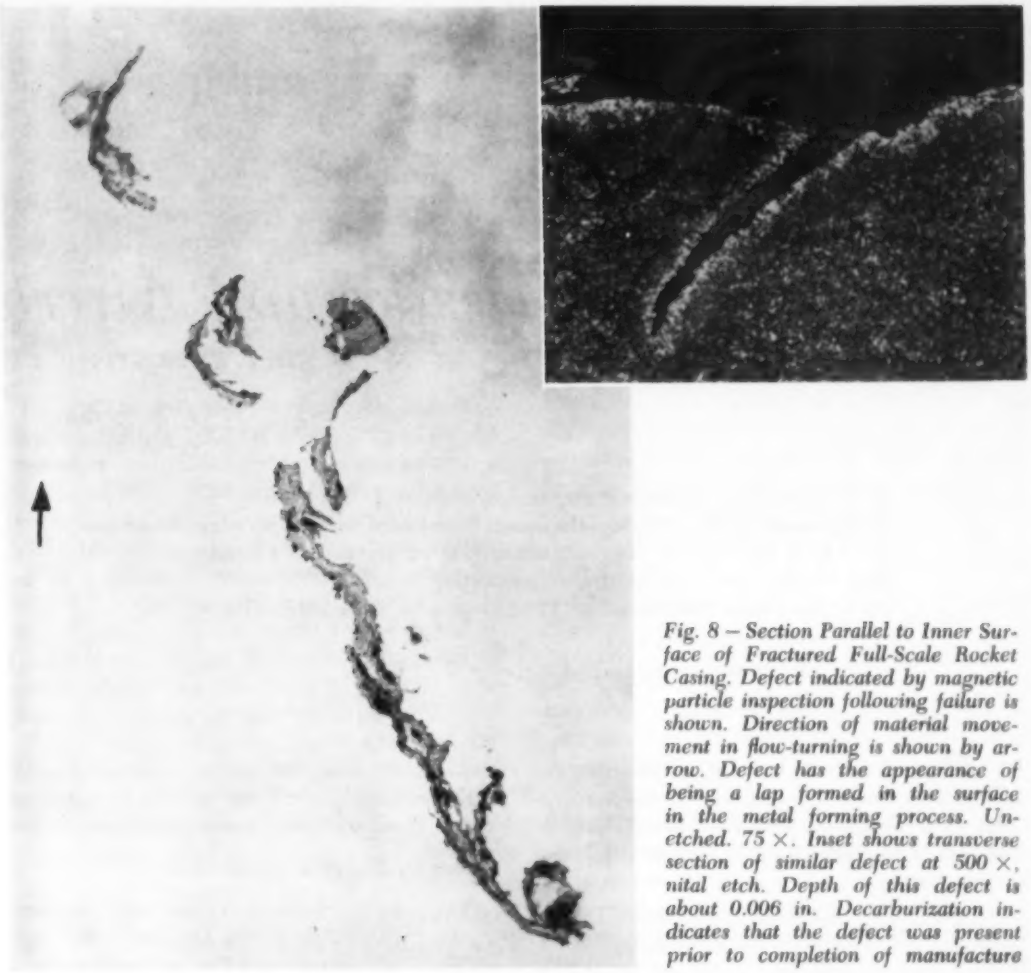

Fig. 8 – Section Parallel to Inner Surface of Fractured Full-Scale Rocket Casing. Defect indicated by magnetic particle inspection following failure is shown. Direction of material movement in flow-turning is shown by arrow. Defect has the appearance of being a lap formed in the surface in the metal forming process. Unetched. 75 ×. Inset shows transverse section of similar defect at 500 ×, nital etch. Depth of this defect is about 0.006 in. Decarburization indicates that the defect was present prior to completion of manufacture

no failure. Another was held at 250,000 psi. for 25 hr. with no failure. The specimen containing the ground and pitted defect was loaded in steps up to 250,000 psi. and ruptured immediately when it reached that stress level. The smooth specimen containing the unrepaired defect ruptured after 2 min. at 280,000 psi., but did not fracture through the defect. Of two notched specimens, one ruptured on loading to 230,000 psi. and one ruptured after loading to 210,000 psi. The elastic stress concentration factor in the notched specimens was 8.2. It will be noted that the material displays notch sensitivity in that the fracture strength in the presence of a notch is somewhat below the yield strength of the smooth material.

None of the tests gave any conclusive evidence for or against the possibility of delayed failure due to hydrogen. However, they seemed to indicate that the gross hydrogen content of the steel was low. This was supported by hydrogen analyses of the material. Four vacuum fusion analyses performed by the National Research Corp. indicated a hydrogen level in the vicinity of 0.7 ± 0.1 ppm. This is a very low figure, but about what one would expect in a vacuum melted material.

The second article will describe the role of hydrogen in the delayed failure of rocket casings. Evidence supporting the hydrogen hypothesis is presented. Subsequent cyclic tests on full-scale vessels will also be described. These tests amply demonstrate that solid-fuel rocket casings to operate at 240,000 psi. are practical and feasible. It is also shown that stress levels up to 260,000 psi. appear possible if small plastic strains can be tolerated.

Magnesium in Missiles and Aircraft

*By T. E. LEONTIS**

Most spectacular advance in magnesium technology has been in the missile field. Alloy developments have raised useful operating temperature to at least 700° F., and designers are relying on magnesium's stiffness, high specific heat, and resistance to buckling for better missile performance. (T24e, Q-general, 2-62; Mg-b, 17-57)

ONE OF THE EARLIEST DEPARTURES from the standard Mg-Al-Zn alloys came with the development of a Mg-Zn-Zr extrusion alloy, ZK 60 A. The higher strength of this alloy permitted and encouraged its use in a variety of aircraft applications. Further increases in compressive yield strength in this composition are being realized by producing ZK 60 extrusions from atomized pellets instead of cast billets. The atomized pellets are produced by allowing the molten ZK 60 alloy to pass through a small orifice, then to a rapidly rotating disk in the center of the atomizing tank. The molten metal is propelled from the disk in the form of small globules which solidify into spherical pellets about 0.016 in. in diameter before striking the walls of the atomizing tank. The operation is performed in an atmosphere of natural gas which also powers the turbine that drives the atomizing disk. Table I compares the properties of billet extrusions (ZK 60 A-T 5) and pellet extrusions (ZK 60 B-B) for several representative sections.

The high compressive yield strength of ZK 60 B-B pellet extrusions is largely attributed to an extremely fine grain size. One example of their use is in the floor substructure of the new C-133 turboprop transports being built by Douglas Aircraft. About 4300 lb. of pellet extrusions are used.

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Alloys for Elevated Temperature

The need for magnesium alloys with improved strength above 300° F. was first met in the early 1950's by the development of magnesium-zirconium alloys containing rare earth metals. EZ 33 A (see Data Sheet, p. 96-B), a representative composition in this family of alloys, has been successful in the form of sand castings in applications where temperatures reach 300 to 450° F.

The rare earth metals in EZ 33 A are added in the form of misch metal. This is a mixture of rare earth elements which are extracted directly from monazite sand, the most common mineral containing them. Extensive research over the last ten years has shown that even higher strength levels in magnesium alloys can be achieved if specific rare earth metals are used. The most effective addition is a combination called didymium, a mixture of about 85% neodymium and 15% praseodymium.

Two new magnesium alloys containing didymium have been introduced recently on a limited basis. EK 31 XA, developed by Dow Metal

Table I – Mechanical Properties of Billet (ZK 60 A-T5) and Pellet (ZK 60 B-B) Extrusions of Magnesium Alloys

	Elongation, %		Yield Strength, Psi.				Tensile Strength	
			Tensile		Compressive			
	Billet	Pellet	Billet	Pellet	Billet	Pellet	Billet	Pellet
10-in. special section	12	15	43,000	40,000	31,000	38,000	52,000	50,000
11-in. I-beam	12	17	41,000	38,000	30,000	40,000	50,000	49,000
12-in. I-beam	13	18	41,000	41,000	30,000	42,000	51,000	51,000
¾ × 6-in. rectangle	14	15	42,000	41,000	29,000	42,000	50,000	50,000
4 × 4 × ⅝-in. angle	14	21	41,000	39,000	27,000	38,000	51,000	49,000
4-in. I-beam	15	19	38,000	39,000	30,000	40,000	50,000	49,000

Products Co., contains 3% didymium and 0.7% zirconium. Alloy QE 22 A contains 2% silver, 2% didymium and 0.7% zirconium. The latter is a development of Magnesium Elektron Limited, and in Great Britain it is called MSR alloy.

The temperature range over which magnesium alloys maintain useful strength is further extended by thorium additions *(Metal Progress,* August 1957, p. 97). These alloys were first introduced in the form of sand castings and later as sheets, plates, and extruded products. Thorium also improves the modulus of elasticity (Fig. 1).

The effect of temperature on the tensile properties of several new and standard casting alloys is shown in Fig. 2. All of the alloys containing thorium (HK 31 A) and the rare earth metals (QE 22 A, EK 31 XA, EZ 33 A) are stronger above 350° F. than the Mg-Al-Zn alloy (AZ 92 A). The advantage of thorium is apparent only at the high end of the useful temperature range for short-time applications. QE 22 A alloy not only exhibits good temperature resistance, but in addition it has the highest yield strength up to 560° F. of any known magnesium casting alloy. It will probably become an important magnesium alloy for sand and permanent mold castings.

Good Structural Metal

Use of magnesium alloys in missile systems may easily exceed that in piloted aircraft and associated equipment. Performance requirements, in general, demand a minimum-weight structure. Thus, missiles must be made of structural materials having high strength-to-weight and rigidity-

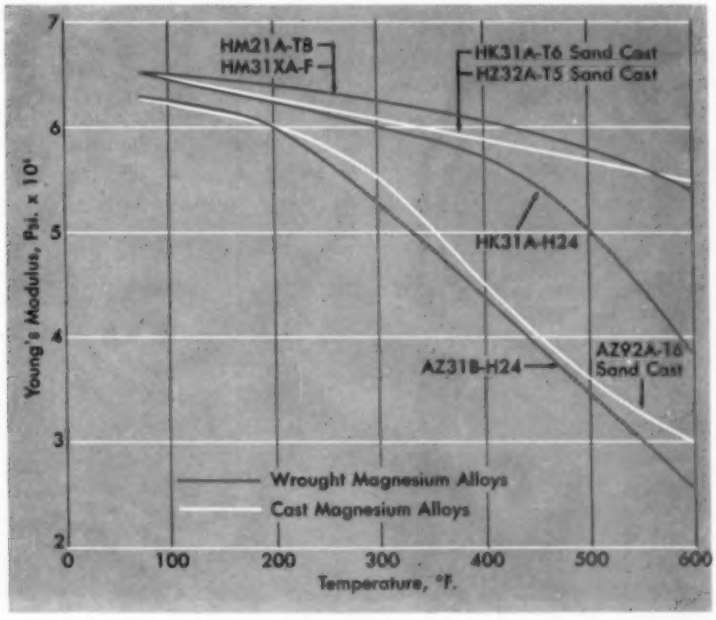


Fig. 1 – Effect of Temperature on the Modulus of Elasticity of Magnesium Alloys

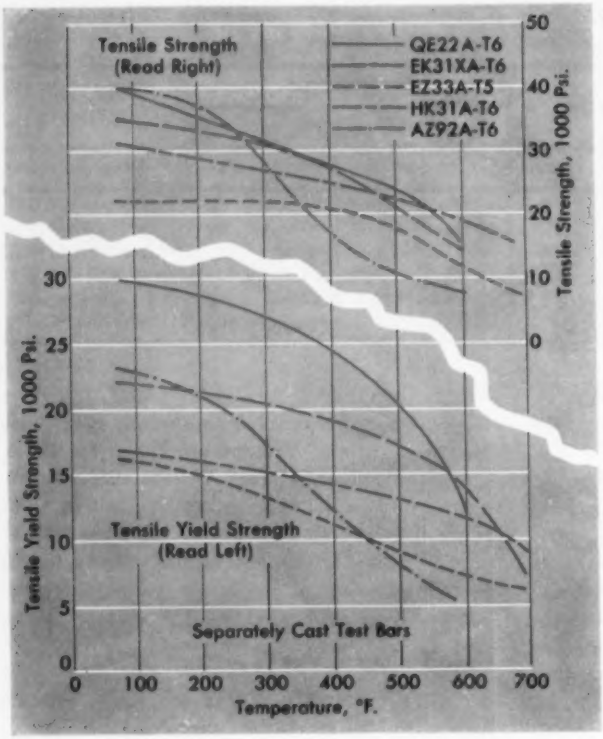


Fig. 2 – Short-Time Tensile Properties of Several Magnesium Casting Alloys

to-weight ratios. Various theoretical analyses employed in structural design demonstrate why magnesium satisfies these prerequisites. One analysis, for example, concerns the resistance to compressive buckling of a column. This is proportional to the parameter, Et^2, where E = Young's Modulus and t = section thickness. With magnesium, missile skins can be made thick enough to prevent buckling without increasing the weight excessively.

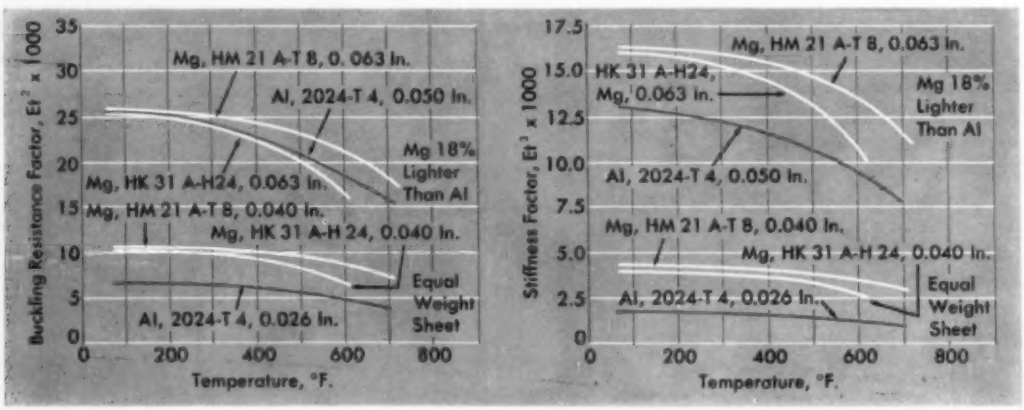
A comparison of HM 21 A-T 8 and HK 31 A-H 24 with another common missile sheet metal for resistance to buckling at temperatures up to 700° F. is made in Fig. 3 (below, left). HM 21 A alloy sheet with an 18% weight saving will have superior buckling resistance at elevated temperatures. If the comparison of the two materials is made at equal weight, the magnesium structure will be approximately 60% stronger than the other structure made of aluminum.

Structural stiffness is another important factor when the problems of aeroelasticity* and flutter are considered. It is proportional to the parameter Et^3. The curves in Fig. 3 (right) show that the HM 21 A-T 8 magnesium sheet designed 18% lighter than the competitive aluminum alloy will be stiffer throughout the entire temperature range. On an equal weight basis, the magnesium sheet will be more than twice as stiff.

Another important property considered in missile design is heat capacity. Magnesium alloys

*This is the area dealing with the interacting effects of elastic deformation and aerodynamic loads.

Fig. 3 – Comparative Resistance to Buckling (Left) and Comparative Stiffness (Right) of Two Magnesium and an Aluminum Alloy in Sheet Form. Upper curves are for magnesium alloys designed 18% lighter than aluminum sheet, and lower curves are for equal weight sheet



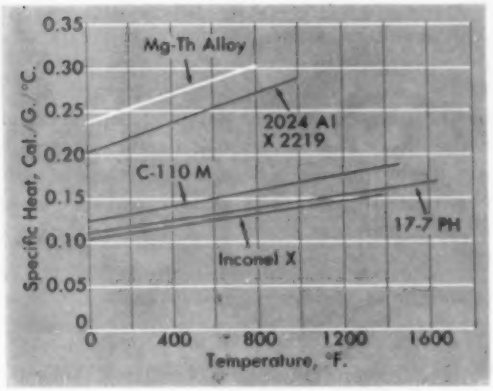


Fig. 4 – Specific Heat Plotted Against Temperature for a Magnesium-Thorium Alloy and a Number of Other High-Temperature Alloys

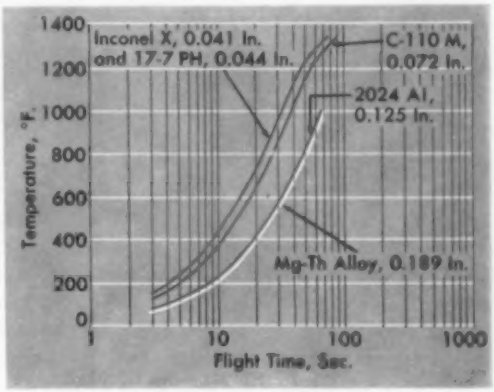
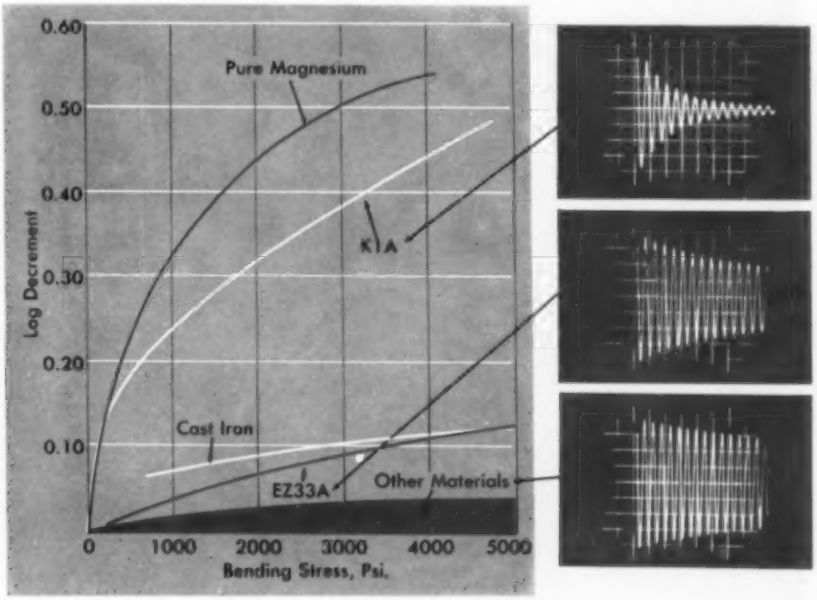


Fig. 5 – Skin Temperature of a Number of Alloys After Various Flight Times. Hypothetical flight conditions are a speed of mach 10 at 100,000 ft., turbulent flow ($Re = 10^7$), and emissivity factor of 0.9

have a high specific heat (Fig. 4). Consequently, they serve as excellent heat sinks when properly used. For the hypothetical flight conditions assumed in Fig. 5, magnesium, on an equal weight basis with three other missile metals, will have a lower skin temperature. This difference can amount to as much as 200 to 300° F., thereby reducing the temperature of internal areas which contain sensitive electronic instruments, ordnance, or fuels. Magnesium also decreases the thermal gradient between hot external skins and cooler internal structure. Thus, there is less chance of structural failure.

High Damping Capacity – An important advantage not often recognized is magnesium's superior damping capacity compared to other metals commonly used in structures. Good damping capacity helps prevent electrical-mechanical malfunctions sometimes caused by high-frequency vibrations at low amplitude which are induced by the launching booster or sustainer power source.

Fig. 6 – Damping Capacity of Sand-Cast Mg Alloys Compared With Other Metals



It appears that the sand and die castings are best and, in general, alloying additions to magnesium decrease its damping capacity. A new alloy, designated K 1 A, has been developed which offers the best combination of damping capacity and castability. The oscilloscope tracings shown in Fig. 6 show the rate of decay of vibrations in various materials. K 1 A is already finding use as support members for portions of missile electronic guidance systems.

Wide Use in Missiles

Recognizing these favorable characteristics, designers have made extensive use of magnesium alloys in at least 20 different missiles. For example, the Falcon GAR-1, an air-to-air missile, is virtually a 90% magnesium structure. The body is made of 0.040-in. AZ 31 B-H 24 sheet which has been rolled, longitudinally welded, and then stretch formed to size. ZK 60 A-T 5 magnesium tubing is also used in the body. The four stabilizer frames are AZ 91 B die castings and the rudders attached to these frames are machined from ZK 60 A-T 5 forgings.

Extensive use of high-temperature magnesium-thorium sheet alloys is made in the Bomarc, a surface-to-air missile. There is 230 lb. of magnesium in each of these missiles, including HK 31 A-H 24 sheet and HM 31 XA-F extrusions used as the leading and trailing edges of the control surfaces. The Marquardt ram-jet engines which

Fig. 7 — Titan Intercontinental Ballistic Missile Leaves a Launching Pad at Cape Canaveral. About 40% of the skin structure of the missile is made of magnesium-thorium alloys

are scheduled to power later Bomarc models are designed with more than 200 lb. HK 31 A-T 6 sand castings and sheet in the diffuser section.

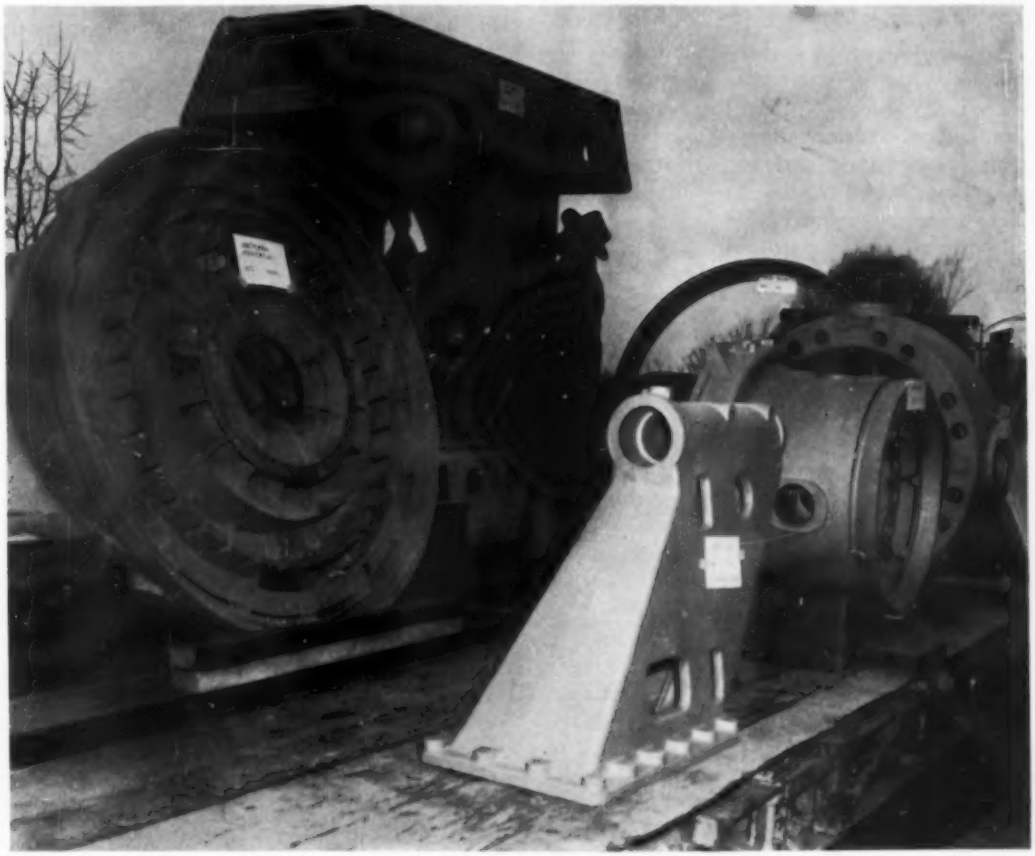
The Mace TM-76, a surface-to-surface missile, uses 640 lb. of AZ 31 B-H 24 sheet in its fuselage and 26 lb. of AZ 91 C-T 6 sand castings. The Titan intercontinental ballistic missile (Fig. 7) contains 2000 lb. of magnesium-thorium alloys in sheet and extruded form. In the Navy's Regulus II a magnesium sand casting (alloy AZ 91 C) cast to a wall thickness of approximately 0.120 in. forms the vertical fin tip. The air intake is a casting weighing 150 lb. and has a nominal wall thickness of 0.24 in. with the solid leading edge tapering to a 0.015 in. radius.

Magnesium alloys have been employed in the Vanguard satellite launching vehicle. The sphere is made of AZ 31 B sheet. More significant, however, the skin of the second stage rocket is made of contoured HK 31 A-H 24. This is an indication of applications to come in future ballistic missiles. Alloy sheet (HM 21 A and HK 31 A) is employed in four transitional sections of the skin as follows: (*a*) between the stage I fuel and oxidizer tanks, (*b*) between stage I and stage II, (*c*) between the stage II fuel and oxidizer tanks, and (*d*) between stage II and the nose cone.

In addition, HM 31 A extrusions are used for the external conduits between fuel and oxidizer tanks in both stages and for such internal structural parts as stringers, longerons and hinges.

Although most of the advances for magnesium have been in the missile field, in terms of weight, size and production volume, the conventional alloys continue to predominate in casting applications of magnesium. Figure 8 shows a group of large castings for the Nike Hercules tracking and guidance antenna system, most being of AZ 91 C alloy. The tall casting has a finished weight of 1450 lb.

Fig. 8 – Cast Parts for Nike Hercules Tracking and Guidance Antenna System. Most of these are made of AZ 91 C, a conventional Mg-Al-Zn alloy



Hot Forming Parts From 17-7 PH Sheet

*By ALFRED F. HOFSTATTER**

With a die quenching treatment, parts of 17-7 PH can be produced to close tolerances without the aid of heat treat fixtures or expensive hand rework. (G-general, J26p; SS, 4-53)

ON FIRST CONSIDERATION, it may seem unnecessary to use hot forming for this alloy, because in the annealed condition it is austenitic and has excellent formability. After forming, 17-7 PH can be heat treated to strengths as high as 220,000 psi. However, as with other alloys hardenable by heat treating, a certain amount of warping accompanies the thermal treatment. After hardening, parts are extremely difficult to straighten or re-form.

A closer look at the heat treatment shows why there is warpage. A two-stage heat treatment is needed to harden 17-7 PH: The first is a martensitic-type transformation; the second is an aging (precipitation hardening) treatment. The most common heat treatment for this alloy is the "TH" treatment outlined below:

1. Anneal, 1950° F., air cool.
2. Condition and transform, 1400° F. for 1½ hr., air cool.
3. Complete the transformation, 55° F. for 30 min. (Maximum time limit from 1400° F. to 60° F. is 1 hr.)
4. Age at 1050 to 1100° F. for desired strength.

During transformation, density decreases, causing an over-all linear growth of 0.005 in. per in., and during aging density increases, causing a linear shrinkage of 0.0005 in. per in. These changes in dimension are fairly constant and corrections in tool design can be made.

Causes of Warpage

On the other hand, corrections cannot be made for the warping which occurs. For example, during the TH treatment, when cooling from the 1400° F. conditioning temperature, parts start to transform (M_s) at about 200° F. and finish transforming (M_f) at about 60° F. As transformation progresses, density decreases, causing dimensional change. If every segment of a part transforms at the same time, there will be little, if any, warping. Two factors prevent this simultaneous transformation from occurring in practice: (*a*) unequal cooling of a part and (*b*) residual cold work which will cause the M_s to occur at a higher temperature.

Because some areas of a part cool faster than others, they start transforming and expand, while the hotter areas have not yet started to expand. Also, any cold work remaining in a part from previous forming operations will raise the M_s in the cold worked area. Even if every segment of a part is cooled equally and simultaneously, the areas which have been cold worked will start transforming ahead of areas which have not been cold worked. In either instance, the areas that have not reached the M_s are trying to restrain the areas that are transforming (expanding).

Since the forces involved in this expansion are much greater than the yield strength of the alloy, deformation will occur. The result is a warped part. Sometimes it is possible to remove the warping by hand work or by restriking on the forming die, but because the material is partially hardened, the success of these operations is doubtful. Even though a warped part is straightened, the aging treatment causes stress-relief, and warping returns.

Control of Warpage

To produce close-tolerance parts from 17-7 PH, a means of correcting or controlling the transformation warpage was needed. First, an attempt was made to fixture formed parts during the transformation treatment. However, this had little effect unless an extremely heavy, sturdy

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Fig. 1 – End-View Comparison of Warpage in Identical Parts Made From 17-7 PH. Bottom part was air cooled from 1400° F. while the one on top was die quenched using equipment in Fig. 3

fixture was used. This interfered with the cooling rate required. The next effort was to fixture the part during aging, but this also was unsuccessful. However, the basic problem – to stop the warping before it occurred – was resolved by restraint during the transformation, but by a method other than fixturing.

We found that the best means to prevent warping was to place the part in the forming die while it cooled from the 1400° F. conditioning temperature. This is known as die quenching.

Prior to die quenching, parts were preformed in the annealed condition, and heated to 1400° F. for 1½ hr. To prepare for die quenching, the parts were cooled to the range 1000 to 700° F. and held there. Parts were removed from the furnace one at a time, and placed immediately in the die. Then the die was closed until the part reached room temperature. Parts were removed, cooled to 55° F. and aged to the desired strength.

Figure 1 shows straightness attained by die quenching, and Fig. 2 shows the process schematically. Areas on the curves which need further discussion are numbered:

(1) Cooling from the conditioning temperature to the holding temperature range – The rate of cooling seems to have no effect on mechanical properties, but the sooner the parts reach the holding temperature the sooner die quenching can begin. The importance of this is explained in paragraph (3).

(2) Holding range temperatures – After parts are heated at 1400° F. for 1½ hr., they must be removed or the mechanical properties of the metal will be affected. Consequently a range of holding temperatures was needed. This determination of holding temperatures was based on the fact that, while cooling from 1400° F., 17-7 PH is the same size at two points on the cooling curve, X and Y (Fig. 2). This is true because, during the cooling process from 600° F. to room temperature, the shrinkage due to thermal contraction is exactly equal to the transformation expansion. No appreciable size change occurs in the process.

It is, thus, imperative that the part be inserted into the die when the metal is at about 600° F. because a finish-size die can be used for die quenching. Therefore the holding temperature

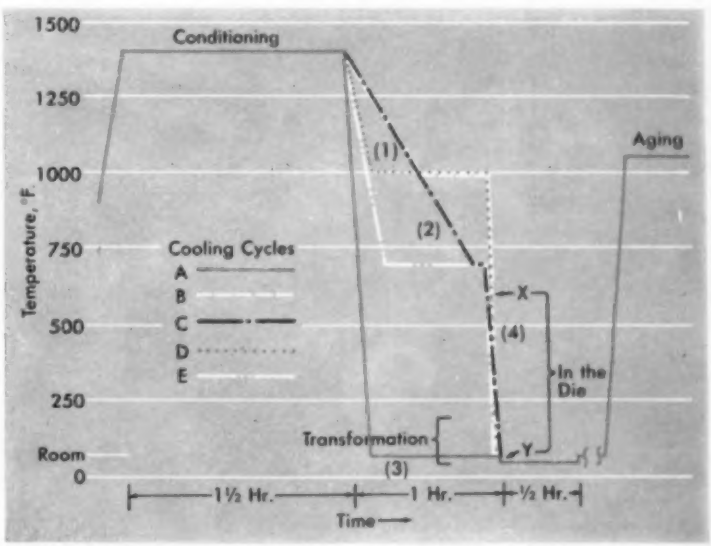


Fig. 2 – Time Plotted Against Temperature for Transformation and Die Quench Treatment of Parts Made From 17-7 PH

Table I – Mechanical Properties of 17-7 PH After Interrupted Cooling Cycles*

Cooling Cycle	0.2% Yield Strength	Ultimate Strength	Elongation in 2 In.
A—Air cool to room temperature (normal "TH" method)	172,800 psi.	182,360 psi.	8.2%
B—Furnace cool to 1000° F.; die quench	171,400	180,800	7.8
C—Furnace cool to 700° F.; die quench	172,030	181,960	8.3
D—Transfer to furnace at 1000° F.; die quench	167,380	180,110	8.5
E—Transfer to furnace at 700° F.; die quench	170,030	182,180	8.5

*Conditioning temperature 1400° F.; cooling cycles shown in Fig. 2. Each value is the result of six samples of two different heats. All samples were aged at 1060° F. for 1 ½ hr.

range must be above 600° F. As a result of the tests (Table I), it was concluded that a holding range of 700 to 1000° F. could be used. The tests also established that mechanical properties of the metal were not affected during the various cooling cycles (shown in Fig. 2 as A, B, C, D and E). The holding temperature is adjusted according to the thickness of the material. Thin parts are held near 1000° F. so that when transferred to the die their temperature will be about 600° F., and conversely thicker parts are held near 700° F.

(3) One-hour maximum time limit to cool a part from 1400° F. to 60° F. – This is a requirement of most TH treatment specifications. If this time limit is exceeded, the treatment can be corrected by cooling lower than 60° F. However, in order to maintain uniform processing this limit of 1 hr. should be observed.

The available holding time, prior to die quenching a load of parts individually, is shown by the length of the horizontal part of the cooling curves in Fig. 2.

(4) Cooling the part in the die – While cooling from 600 to 200° F., a part will contract thermally. In the range of 200 to 70° F., it will expand due to transformation, as well as contract thermally. This means that, initially, a part tends to shrink in the die, then expand. Therefore, a minimum of die pressure should be used to prevent binding. This factor must be gaged for each situation. Only enough pressure is needed to keep the part from warping away from the die contour.

As a result of this die quenching treatment, 17-7 PH parts can be manufactured to close tolerances without the aid of heat treat fixtures or expensive hand rework.

Fig. 3 – Die Quenching Setup. Part has been removed from holding furnace and is being placed in the die, which will be closed until the part is cold

Austempering Typewriter Parts

*By DONALD FLANNERY**

A new mechanized salt bath installation can heat treat 14,000 type bars every hour. Costs are lowered and rejections are minimized because hardness and dimensions are consistent from batch to batch. (J26p, J2; ST)

OF THE MORE THAN 2000 PARTS of a standard typewriter, none plays so important a role in performance as the 42 type bars. The ideal bar should be hard enough to withstand constant hammering without excessive wear or deflection, soft enough to take a severe bend without fracture, rigid enough to hold its complex shape, and flexible enough to follow the bar guides smoothly.

Naturally, such a combination of properties is not easy to attain. We managed it by shifting from oil quenching to austempering. This process, performed in an Ajax salt bath installation, gave us toughness without sacrificing other important properties. It also eliminated distortion and scale formation, doubled production, and reduced labor and material costs. This article outlines the reasons for and the results of this change in practice.

Why Oil Quenching Wasn't Good Enough

On a properly adjusted manual machine, type bars only rarely need direction from the guides. But on an electric typewriter, a motor moves the type bars much faster than do fingers. Thus, centrifugal force is greater, and pulls the type head, which is relatively heavy, outward in too wide an arc. As a result, type bars may make frequent and positive contact with the guides, accelerating wear at the type ends by a substantial factor.

Previously we had hardened type bars in a controlled-atmosphere electric furnace. They were then quenched in oil, and tumbled to remove scale. Tempering and roll straightening (to correct warpage) completed the process. Although the results were satisfactory for standard and portable machines, tougher bars were needed for the new electrics.

Austempering, a method for converting the structures of steel to 100% bainite, was the most promising way to achieve that toughness. In this process, pieces are austenitized, rapidly quenched to the bainite range and held at that temperature until transformation is complete.

Two techniques were considered. The approach finally chosen was suggested by Ajax Electric Co. and based on proved automatic salt bath techniques. After serious study, a completely automatic unit was installed in the Royal McBee typewriter plant at Hartford, Conn.

Unit Features Unique Design

Several interesting features of this unit deserve comment. For example, austempering depends on the rapid and uniform quenching of parts after austenitizing. This difficult task is assured by an unusual "cataract" quench that draws the salt down, around, and through the work. Reversing the expected flow pattern, it achieves unprecedented quenching capacity. Because the flow of molten salt is concentrated in the work area and the velocity is closely controlled, practically any requirement of the TTT curve can be met precisely.

Another unusual aspect of the equipment is the addition of a "separating chamber". This is connected to the quench chamber by a narrow slot, and operates at a considerably lower temperature than the quench itself. Austenitizing is carried out in chloride salts. There is a certain amount of carry-over of these salts to the nitrate-nitrite salt bath quench which in time would reduce quench efficiency. As the molten salt circulates into the cooler separating chamber, however, the chlorides are precipitated. Purified nitrate-nitrites automatically return to the

*Chief, Equipment Engineering, Royal McBee Corp., Hartford, Conn.

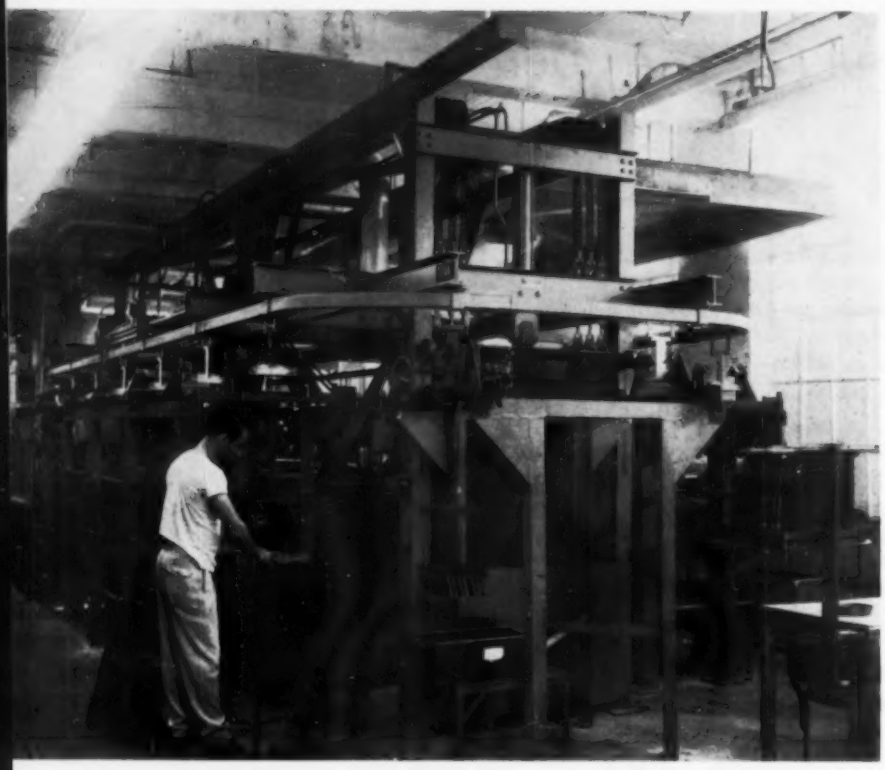


Fig. 1 – This Mechanized Salt Bath Installation Can Austemper 14,000 Type Bars Every Hour. The load-unload end of the unit is shown with the mechanism in down position. Operator is placing fixture in position

quench to keep it operating at peak efficiency.

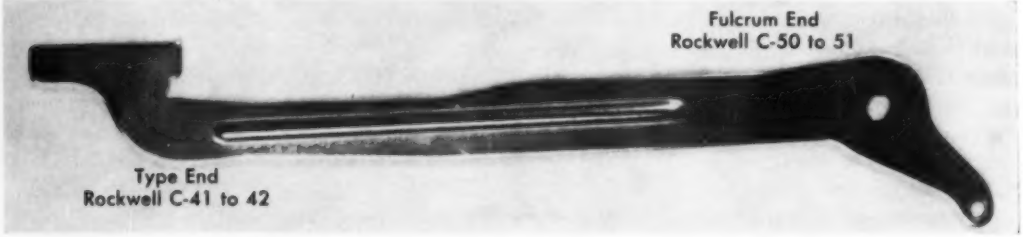
Perhaps an outline of the heat treatment procedure will give a better idea of how the equipment operates. To begin with, type bars are fabricated from C-1055 strip, 0.0400 to 0.0405 in. thick. Bars are manually racked 61 to a fixture. Eight fixtures comprise a load; these are hung from the track of the indexing elevator mechanism (see Fig. 1). This carries the bars to a neutral salt bath where they are austenitized for 4 min. at 1520° F.

Next the loads are rapidly shifted (in 4 to 5 sec.) to a second in-line nitrate-nitrite salt bath. Here they are quenched at 710° F. (or 615° F., depending on the work needs). A self-dampening mechanism keeps the work from swinging. Transfer speed is a highly essential feature of the austempering cycle because type bars, being small and thin, cool rapidly.

To obtain specified softness in the type ends while retaining hardness at the fulcrum ends, the bars are selectively tempered. With the bars carefully and uniformly fixtured, only the type ends are immersed in an 850 to 870° F. salt bath.

Hot and cold rinsing follow, the work being transferred through all steps by the indexing elevator mechanism. As a final step, the rack wires are withdrawn and the bars drop into wire baskets in a protective oil bath.

Fig. 2 – Typical Type Bar Showing Hardness Needed at Ends. Varying hardness is achieved by selective tempering



Bars are then checked for hardness, toughness, and dimensional conformity. Royal regularly achieves a hardness of Rockwell C-50 to 51 at the fulcrum end and 41 to 42 at the type end of the electric and standard bars. Bars for portables are softer, however. They need a fulcrum hardness of Rockwell C-45 and a type end hardness of 35 to 39. Three dimensions are checked: relation of banking ring shoulder to center line (±0.001 in.); relation of type end face to center line (±0.002 in.); and flatness 0.012 in. average deflection end to end). To check toughness, bars are locked in a "trolley" fixture. Then the type end is bent at an extreme angle to the bar. Unless the bend is perfect in every respect, the entire load of 488 bars is rejected.

Production Raised, Costs Lowered

With the new installation, 14,000 bars can be treated every hour. Previous capacity was 8500 bars per hr. The roll straightener hasn't been used since the austempering installation went on line. Rapid and extremely uniform heating, combined with the support of the dense salt bath, keeps distortion well below acceptable limits without straightening. And while bars are still tumbled, it's only to round off sharp edges for plating. The salt bath seals out all air, protects the part during transfer with a film of salt, and completely prevents scale formation.

Austempering has substantially cut direct and indirect labor, and scored a 45% reduction in defective parts. As a totally unexpected dividend, the installation is also used for treating several other small typewriter parts which benefit from austempering.

How does Royal feel about austempering? Pretty good. In fact, the company is pleased to such an extent that they have ordered a second austempering unit, almost identical with the first, for their new Springfield, Mo., portable typewriter plant.

Book Review

Brass and Bronze Foundry Operations

*Reviewed by Harold J. Roast**

BRASS AND BRONZE FOUNDRY PRACTICE, by Harry M. St. John, Penton Publishing Co., Cleveland, 1958. 244 p., $8.00.

THIS BOOK DESCRIBES, in thorough detail and readable style, the way to avoid or overcome foundry problems. It should appeal not only to engineers and production specialists but also to the "boss" in the inner office since it describes at one end of the scale such items as core-making and molding, and at the other end statistical control and the profit and loss statement. In between, it discusses metallurgy, furnaces, design. The book includes abundant application data, specifying metal composition and how and why to avoid specific impurities.

It is good to see in the first chapter that "the day of miscellaneous scrap as a suitable material for brass foundry use has passed".

The discussion of "metal losses and balances", although brief, is one of the most original and informative chapters in the book. In it foundry "X" represents a poorly run foundry and foundry "Y" one that is well operated. Under the heading of losses that reduce the percentage of acceptable metal castings, we find the following items: nonmetallics in charge, melting loss, skims and

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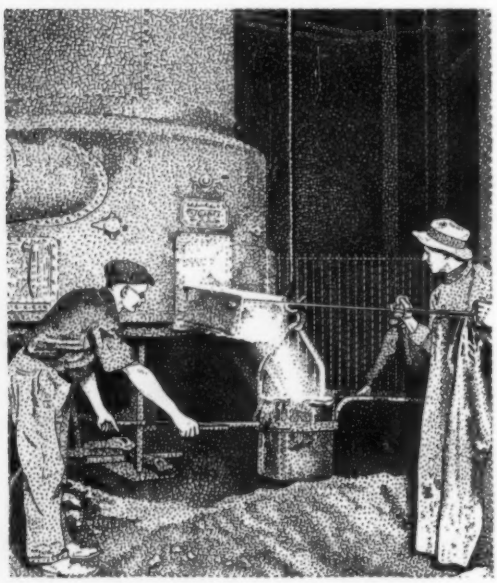
spills, pouring loss, sand-blasting, grinding loss, scrap (from rough castings), machine turnings, scrap (finished castings). The total percent of unsalable castings is 72.5 for "X", and 46.2 for "Y". This means that "X" only gets 27.5% salable castings from metal charged, while "Y" gets 53.8%. The net metal loss (gates, sprues and turnings are recoverable) is for "X" 12.1% and for "Y" 2.1%. Foundries are now operating between both extremes and it would be well for foundry operators to give time and study to this chapter.

The author makes another important contribution in the area of "statistical control of scrap". It should stir many a manager into action. His concern is not with statistical quality control – a study which, though rewarding, enters the mathematical field. Rather, the author concerns himself with the time-tested comparison charts and indicators. For example, one deals with a typical daily scrap report card giving item, pattern number, molder number, number and weight of defectives, and nature of defect. Another is a monthly production and scrap card. Still another is a rough casting record, which analyzes and compares good and defective castings. Descriptions are straightforward; formulas demand only the simplest mathematical approach. The operation of a foundry today without some such systematic attempt to keep track of the castings from start to finish is bound to end in failure. The reviewer is pleased that density or specific gravity tests are emphasized.



In the discussion of risers, the efficiency of risers fed directly from the sprue is compared with risers that are at a distance from the sprue, and in the instance of the blind riser, although the author points out that the feeding action of gravity is partially offset by the reduced air pressure set up at the top of the riser cavity, he does not mention the advantage derived if the top of the blind riser is connected through the sand to the atmosphere.

No book based essentially on the extensive experience of the author can be expected to cover all the diverse problems encountered in foundry work. To some the lack of guidance in the making of large castings and the gating and risering of the same might be considered an omission, but, on the other hand, books that supply more information along these lines are parsimonious in their treatment of the best methods to use in a production foundry where thousands of similar castings are made every day. This book happily fills the gap left by its predecessors so that the one complements the other. For the foundryman who has to make large castings it would have been helpful had the author drawn attention to the electric mains frequency furnaces operating both in Europe and North America, not to mention the multiductor type operating on three-phase, 60-cycle power, and having no moving parts. The latter furnaces are now being used both in Canada and the United States.

Many worthwhile suggestions are contained in a chapter entitled "Brass Foundry Economics". The reference to "overhead", namely, "by far the largest part of any casting cost is its share of the plant's burden", is entitled to be printed in capital letters.

The reviewer in his visits to numerous foundries both in the United States and Canada has frequently been astonished at the emphasis placed upon actual cost of manufacture of the castings to the almost entire neglect of that overshadowing nemesis "overhead", especially when estimating the cost, and subsequently the selling price of a new casting.

As I read this book by my old friend St. John, I can visualize him going through one of the large foundries putting his finger on the weak spots of operation with almost unerring judgment. Readers of this book are sure to be convinced that there is much more to the successful operation of a foundry than just making castings. The book fills a real need and therefore should be added to the library of all those engaged in brass and bronze foundry operations.

Welding Nodular Cast Iron

*By R. C. BATES**

Arc welds in nodular iron contain carbide layers at the fusion lines which lower the ductility and impact properties. Postweld annealing eliminates carbides and improves ductility. Oxy-acetylene welds made with nodular iron and Ni Rod 55 are free from carbides, but have high transition temperatures. (K1, K2; CI-r)

SINCE ITS INTRODUCTION in the years after World War II, nodular iron has become an important material for castings. Its properties and economies are attractive to designers. Unfortunately, many applications have been bypassed because available welding techniques did not provide joints with properties comparable to the parent material.

Actually nodular iron can be welded as easily as can gray cast iron since their microstructures differ primarily in the shape of the graphite particles. However, the welds obtained in both materials are generally fragile because brittle carbides form in the weld zone. Post heat treating was reported to be of little value because the extremely small graphite nodules which form upon decomposition of the carbide were believed to reduce ductility.

In most of the early investigations, made shortly after nodular iron appeared, ductility of only 8 to 10% elongation in annealed material was common. Today, nodular iron produced by our Trafford foundry possesses elongations of 18 to 22%. Because of these better properties, we took another look at the welding characteristics.

Welding With An Arc

Arc welding procedures for Ni Rod 55 electrode were first evaluated. (Later, the program included an appraisal of oxy-acetylene welding procedures with nodular iron for a filler metal.) Nodular iron plates supplied by Trafford were 14 in. long, 5½ in. wide and 1 in. thick, and had a composition of 3.68% C, 2.23% Si, 0.041% P, 0.06% Mg, 0.70% Ni and 0.44% Mn. Annealing (for 4 hr. at 1650° F.) and slow cooling produced a ferritic matrix. The mechanical properties (which are typical for Trafford material) were: 62,600 psi. ultimate tensile strength, 47,900 psi. yield strength, and 20% elongation in 2 in.

Welding was done at the Metals Joining Laboratory. To begin with, plates were placed in holding fixtures so that the 30° bevels formed a single Vee with a 60° included angle and a ⅛-in. root opening. With a thin slice of nodular iron as a back-up bar below the root opening, the entire fixture and plates were preheated at 600° F.

Approximately 20 passes with Ni Rod 55 welding electrodes completed each weld. Each pass was preceded by peening and wire brushing. Preheat was maintained at 600° F. with an oxy-acetylene torch, temperature being measured frequently with a contact pyrometer. We found the wetting characteristics of the Ni Rod to be good. Metallographic examination, slow bend tests, tensile testing and impact testing of the plates followed.

Microscopic Examination

Figure 1 shows nodular cast iron as annealed: the structure consists of spheroidal graphite embedded in a matrix of ferrite. A typical weld in the as-welded condition is shown in Fig. 2. Adjacent to the weld metal (austenitic nickel-iron) lies a continuous layer of hard and brittle carbide.

An extremely rapid cooling rate is responsible for this phase. Some of the base metal melts

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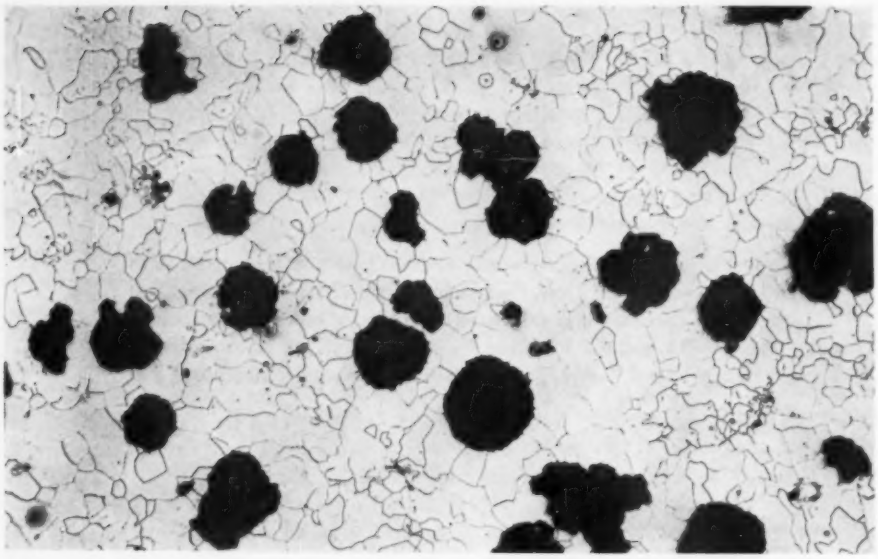

Fig. 1 – Annealed Nodular Cast Iron Structure Consisting of Graphite Spheroids Embedded in a Ferrite Matrix. Etchant, 2% nital; 250 ×

during welding; it freezes and cools rapidly because of the large mass of relatively cool base metal adjacent to the very thin molten layer. Solidification is, therefore, not unlike that which occurs in a chill casting, and the resulting structure is similar to white iron.

Examination of the phase next to the carbide phase at magnifications up to 1500 diameters failed to resolve the structure. Since the hardness is equivalent to Rockwell C-22, the phase probably is spheroidized pearlite. Its properties would be similar to those of lamellar pearlite of equivalent hardness. At greater distances from the weld zone, greater and greater amounts of ferrite are found. Eventually, the structure is completely unaffected, and consists of ferrite and spheroidal graphite.

Annealing at 1650° F. followed with slow cooling decomposes the carbide network and converts the structure of the heat-affected base metal to a mixture of ferrite and nodular graphite. At the fusion lines, however, many tiny particles of nodular graphite are present.

An additional point concerning Fig. 2: The dark phase present in the weld metal is believed to be graphite. Much of it has a flake structure, and probably decreases the ductility of the weld metal. Graphite probably results from the carbonaceous flux which coats the welding electrode.

The tensile and yield strengths of arc weldments of annealed nodular iron are comparable to those of the base metal. The average values found were 60,500 and 44,000 psi., respectively. Elongation in 2 in. was 10%. As-welded tensile specimens exhibit slightly higher strength, but the elongation is only 1 to 2%.

What Bend Tests Proved

Bend tests were performed on unwelded control samples, as-welded samples, and samples annealed after welding. Though most of the samples were tested with the roots of the welds in tension, some as-welded specimens were tested with the weld faces in tension. To aid measurement, lines were inscribed at ⅛-in. intervals on all specimens before testing. Spacing beween these lines was measured after testing.

The unwelded control samples bent an average of 30°. Although most bending occurred near the center line, there was some bending within ¾ in. of each side of the center line. Bending in the as-welded sample amounted to only a total of 2°, and was entirely restricted to the weld metal in an area of less than ⅛ in. on each side of the center line.

No elongation was recorded across the fusion lines. Despite the total lack of strain across these lines (in the as-welded samples), cracks always occurred there. This shows that the continuous carbide network at the weld metal-parent metal interface is brittle and will not support a bending load. Despite this lack of ductility, however, the

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Average Properties of Type 4340 Steel, 3-inch section, oil quenched, tempered at 1000°

Tensile strength	175,000 psi
Yield strength	155,000 psi
Elongation in 2"	14%
Reduction of area	46%
Hardness	Brinell 370

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*Properties of Magnesium Alloys**

Form	Alloy (A.S.T.M.)	Temper	Nominal Composition				Typical Mechanical Properties†			100-Hr. Creep (1000 Psi.) 0.2% Total Extension		
			Al	Th	Zn	Zr	Tensile (1000 Psi.)	Tensile Yield	Elongation in 2 In.	200° F.	400° F.	600° F.
Sand and permanent mold castings	AZ 63 A	–T4	6.0	–	3.0	–	40(*15*)	14(*11*)	12(*20*)%	7	–	–
	AZ 81 A	–T4	7.6	–	0.7	–	40(*20*)	14(*11*)	12(*30*)	–	–	–
	AZ 91 C	–T4	8.7	–	0.7	–	40(–)	14(–)	11(–)	–	–	–
	AZ 91 C	–T6	8.7	–	0.7	–	40(*17*)	19(*12*)	5(*40*)	–	–	–
	AZ 92 A	–T6	9.0	–	2.0	–	40(*17*)	21(*12*)	2(*36*)	8	1.5	–
	EZ 33 A (*a*)	–T5	–	–	2.7	0.7	23(*21*)	15(*11*)	3(*20*)	–	8	1.0
	HK 31 A	–T6	–	3.0	–	0.7	30(*24*)	15(*14*)	8(*17*)	–	10	3.0
	HZ 32 A	–T5	–	3.0	2.1	0.7	29(*17*)	14(*10*)	7(*33*)	–	8	3.5
	K 1 A	–F	–	–	–	0.7	26(*2*)	8(–)	19(–)	–	–	–
	ZK 51 A	–T5	–	–	5.0	0.7	40(*17*)	24(*13*)	8(*17*)	–	–	–
	EK 31 XA (*b*)	–T6	–	–	–	0.6	35(*29*)	22(*20*)	4(*17*)	–	9	1.4
	QE 22 A (*c*)	–T6	–	–	–	0.7	40(*28*)	30(*25*)	4(*22*)	–	9	–
	ZH 62 A	–T5	–	1.8	5.7	0.7	40(*19*)	27(*15*)	8(*28*)	10.8	3.6	–
Die castings	AZ 91 A	–F	9.0	–	0.7	–	33(–)	22(–)	3(–)	–	–	–
	AZ 91 B	–F	9.0	–	0.7	–	33(–)	22(–)	3(–)	–	–	–
	K 1 A	–F	–	–	–	–	23.5(–)	11.5(–)	7.5(–)	–	–	–
Extrusions	AZ 31 B	–F	3.0	–	1.0	–	38(–)	29(–)	15(–)	7	–	–
	AZ 61 A	–F	6.5	–	1.0	–	45(*21*)	33(*14*)	16(*42*)	7.5	–	–
	AZ 80 A	–T5	8.5	–	0.5	–	55(–)	40(–)	7(–)	–	–	–
	HM 31 XA (*d*)	–F	–	3.0	–	–	42(*24*)	33(*22*)	10(*32*)	–	12	5
	ZK 60 A	–T5	–	–	5.7	0.55	53(*15*)	44(*12*)	11(*84*)	3.9	–	–
Sheet and plate	AZ 31 B	–H24	3.0	–	1.0	–	42(*13*)	32(*8*)	15(*82*)	4.0	–	–
	AZ 31 B	–O	3.0	–	1.0	–	37(*13*)	22(*8*)	21(*82*)	8	–	–
	HK 31 A	–H24	–	3.0	–	0.7	37(*24*)	28(*21*)	8(*21*)	–	7	–
	HK 31 A	–T6	–	3.0	–	0.7	37(*23*)	21(*15*)	14(*19*)	–	10	2.0
	HM 21 A (*e*)	–T8	–	2.0	–	–	34(*17*)	21(*15*)	12(*32*)	–	10.5	5.0
	ZE 10 A	–H24	–	–	1.2	–	38(–)	28(–)	15(–)	–	–	–
	ZE 10 A	–O	–	–	1.2	–	33(–)	23(–)	23(–)	–	–	–
Tooling plate	AZ 31 B	–F	3.0	–	1.0	–	35(–)	19(–)	12(–)	–	–	–
Tread plate	AZ 31 C	–F	3.0	–	1.0	–	35(–)	19(–)	14(–)	–	–	–

*Source: Brooks & Perkins, Inc. and Dow Metal Products Co., a Division of Dow Chemical Co.

†Parentheses and italics show short-time properties at 400° F.; others are room-temperature properties.

(*a*) Contains 3.0% rare earths. (*b*) Contains 3.0% didymium (a mixture of about 85% neodymium and 15% praseodymium). (*c*) Contains 2.0% didymium and 2.5% silver. (*d*) Contains 1.5% manganese. (*e*) Contains 0.6% manganese.

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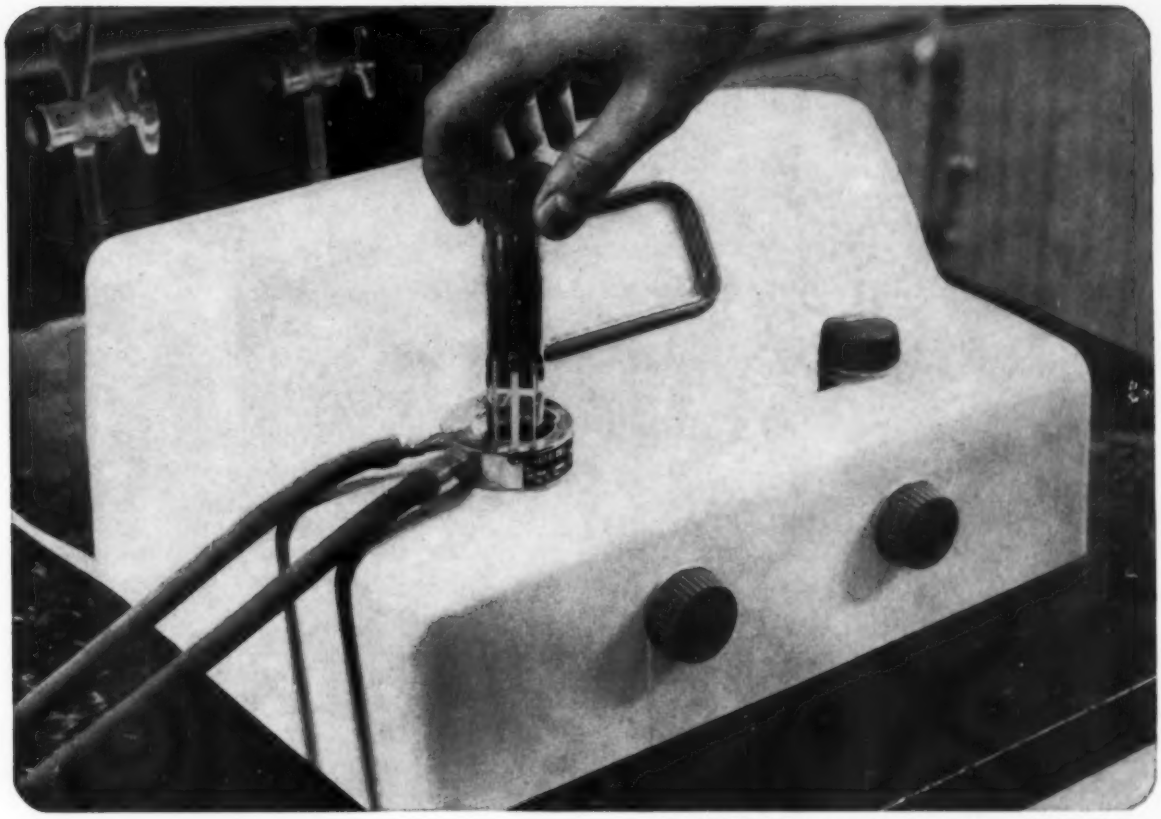

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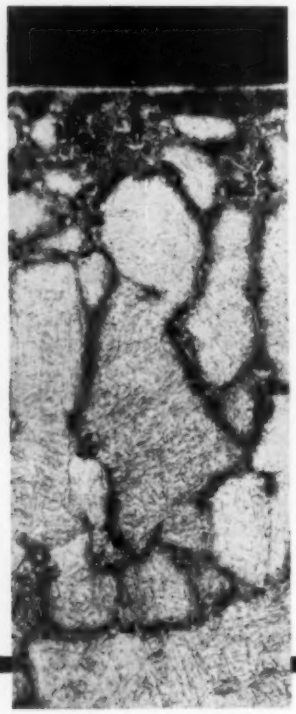

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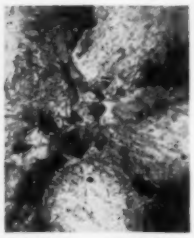

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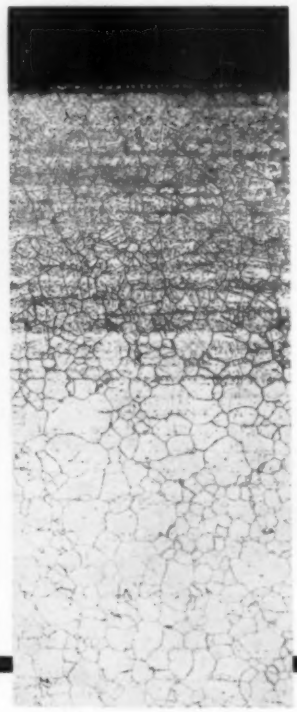

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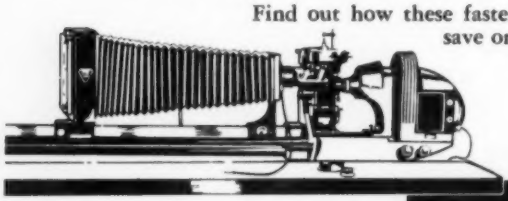

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strength of the as-welded joints is equivalent to that of the base metal. Thus, such welds should be considered for applications where only strength, rather than ductility or impact resistance, is needed.

An average bend of 14° occurred during the root bend tests of the arc-welded samples which had been annealed after welding. Most of the elongation was recorded across one of the fusion lines despite the numerous small graphite nodules evident in the microstructure. These tiny particles are apparently not nearly as harmful as previously believed. Also, the ductility exhibited in these tests and the tensile tests is good enough for most applications.

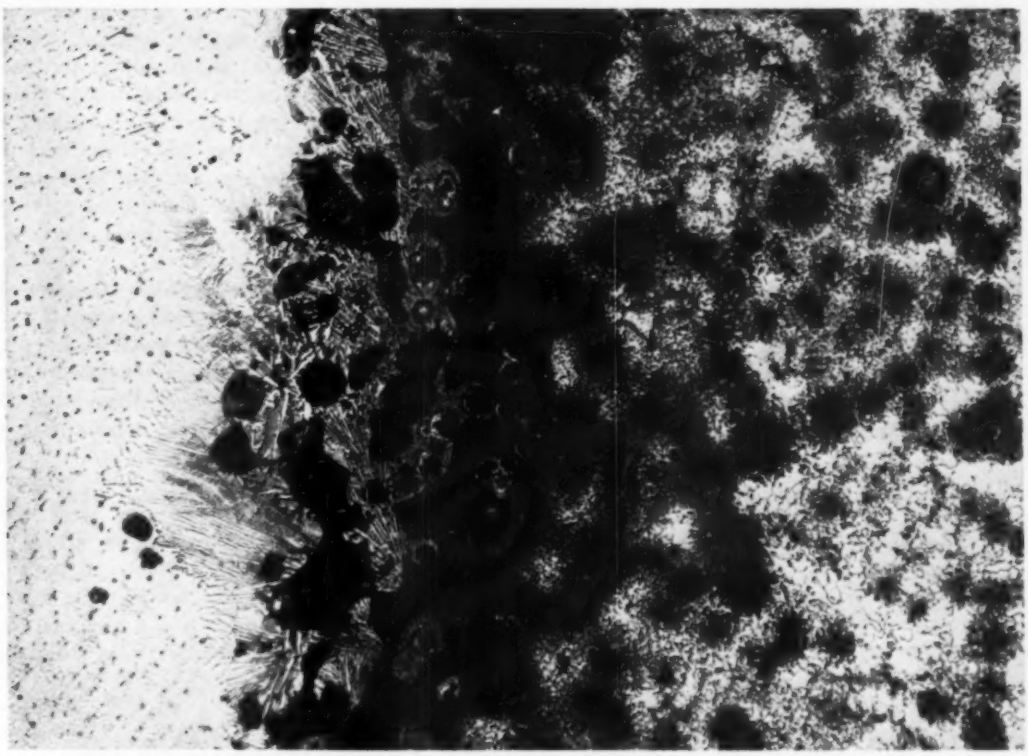


Fig. 2 — Weld Zone in "As-Welded" Nodular Iron. Note white iron (Widmannstätten structure) formed at weld interface. This structure is brittle, and leads to brittleness in the weld. Etchant, 2% nital; 100 ×

Transition Temperature and Nodular Iron

Nodular iron, like many other ferrous materials, exhibits a brittle fracture below what is referred to as the ductile-brittle transition temperature. Actually, the term "transition temperature" is rather indefinite because the transition from ductile shear fractures to brittle cleavage fractures is one which occurs over a relatively wide range of temperature. To evaluate the impact characteristics of the welded and annealed samples, drop-weight specimens were prepared. In this test, a specimen 14 in. long is supported on rests, and a weight of standard size is dropped from a specified height. A notch is provided, usually, by placing a brittle weld bead across the center of the specimen which introduces a running crack after about a 3° bend. A stop prevents bending beyond 5°. Thus, if the specimen breaks during such a test, the mechanism of fracture is primarily cleavage. This is a very brittle type of failure, and complete failure of drop-weight specimens occurs at temperatures below the "nil-ductility transition temperature". The nil-ductility transition temperatures of both unwelded samples and samples annealed after welding were –120 and –95° F., respectively. Thus, arc welding, if followed by an annealing treatment, causes no significant change in the transition temperature. Figure 3 shows the broken half of a drop-weight specimen tested at

–96° F. Above –96° F., the welded nodular iron samples which were annealed did not break even under the severe impact loading of the test. Since the fracture did not follow the fusion lines in low temperature tests and no fracture occurred above –96° F., the harmful carbide layer in as-welded nodular iron had apparently been eliminated by annealing. The decomposition products left from this carbide layer are not harmful to the mechanical properties, and the resulting joint is adequate for most applications – even those which require impact loading.

No Carbides in Oxy-acetylene Welds

While adequate properties could be obtained in annealed arc weldments, the test results on as-welded joints were not encouraging. Only where no ductility was needed could as-welded joints be used. However, a way out soon appeared. In the *Welding Journal*, September 1957, p. 410, Day, Snyder and Inskeep of the Linde Co. reported that they had successfully prepared carbide-free welds possessing high as-welded ductility. No postweld heat treatment was needed. They did this with an oxy-acetylene welding technique and a specially prepared nodular iron welding rod.

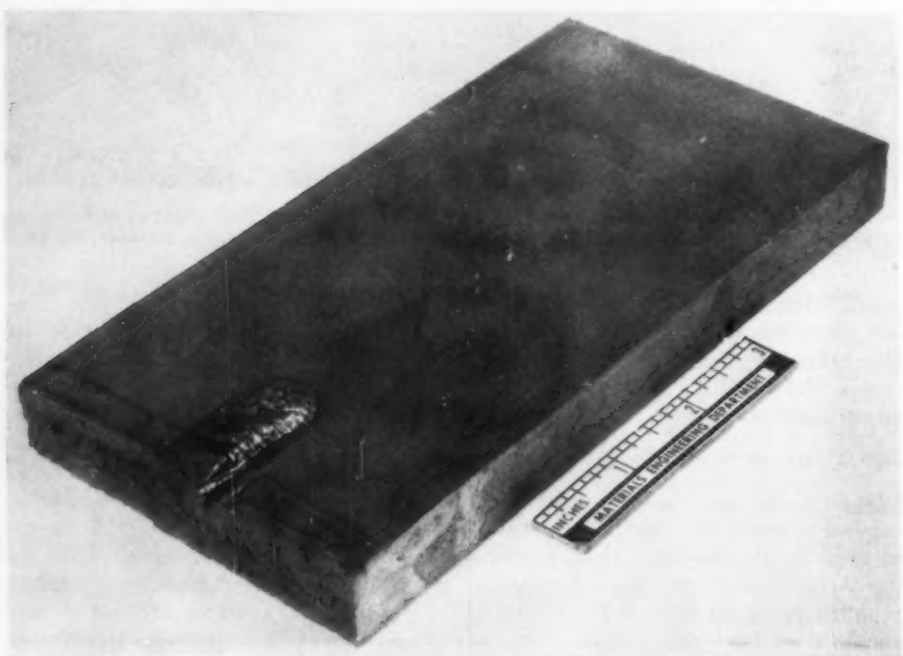
Thus our investigation, originally intended to evaluate only metal-arc welding, was expanded to include the Linde technique. Welding rod and recommendations for welding procedures were obtained from Linde, and plates similar to those previously described were welded.

The samples were placed on firebrick so that the beveled ends formed a single Vee of 60° with a ⅛-in. root opening. (Unlike the setup used for arc welding, no restraining fixtures were used.) First, plates were preheated to 800° F. with the torch. A neutral flame (25 to 30 lb. oxygen and about 10 lb. acetylene) did the welding. Filler metal was Linde Oxweld 69 nodular iron rod, and the weld was fluxed with Oxweld Ferro. Once a puddle was established, successive passes were made continuously until the weld was completed. About six passes were necessary for each weld. After welding, the sample plates were covered with submerged arc flux and cooled slowly to room temperature.

One weld was cracked, but all others were sound except for porosity. Poor wetting in the root area was also encountered, but this was later eliminated with a slightly wider root opening.

Figure 4 shows the interface of the weld metal and parent metal near the root of one of the

Fig. 3 – Welded and Annealed Specimen Which Has Been Tested With a Dropped Weight at –96° F. Brittle failure did not occur in the fusion zone; this indicates that the brittle carbide zone has been removed by annealing



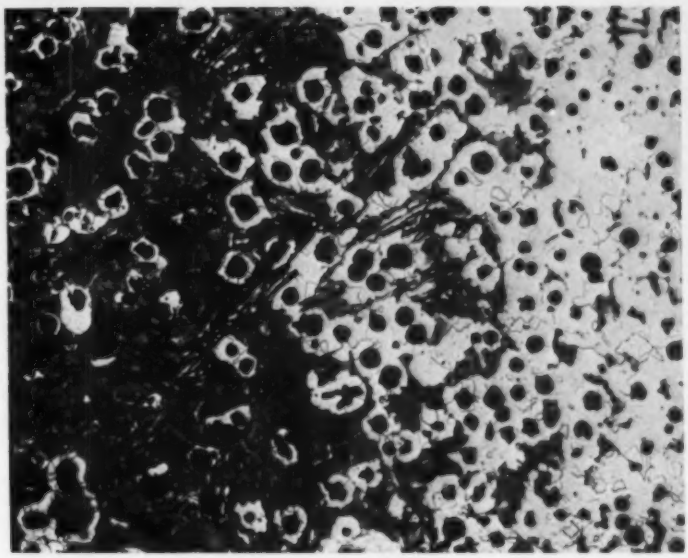


Fig. 4 — Junction Near Root of Weld in Nodular Iron. This weld was made by oxy-acetylene technique with a Linde rod. Note that there is no brittle carbide zone. However, welds produced by this method have high transition temperatures. Etchant, 2% nital. 100 ×

welded joints. The matrix of the weld metal consists of ferrite with small patches of pearlite. Graphite nodules, while smaller than those of the base metal, are spherical. While the interface contains some carbide, the amount is small compared to that contained in the arc-welded samples. In fact, no carbide existed except in the root area, which is illustrated. Other samples examined contained no carbide whatever.

The question arose as to whether it was the special composition of the Linde rod (it contained 3.2% Si) that was responsible for the lack of carbide in the weld zone, or whether the oxy-acetylene welding technique causes slow cooling rates which allow solidification to proceed without carbide formation. To check this, a sample of nodular iron was oxy-acetylene welded with Ni Rod 55 from which the coating had been removed. Welding was difficult because the melting point of the Ni Rod was considerably higher than that of the base metal. An extremely porous weld resulted; however, no carbide was formed.

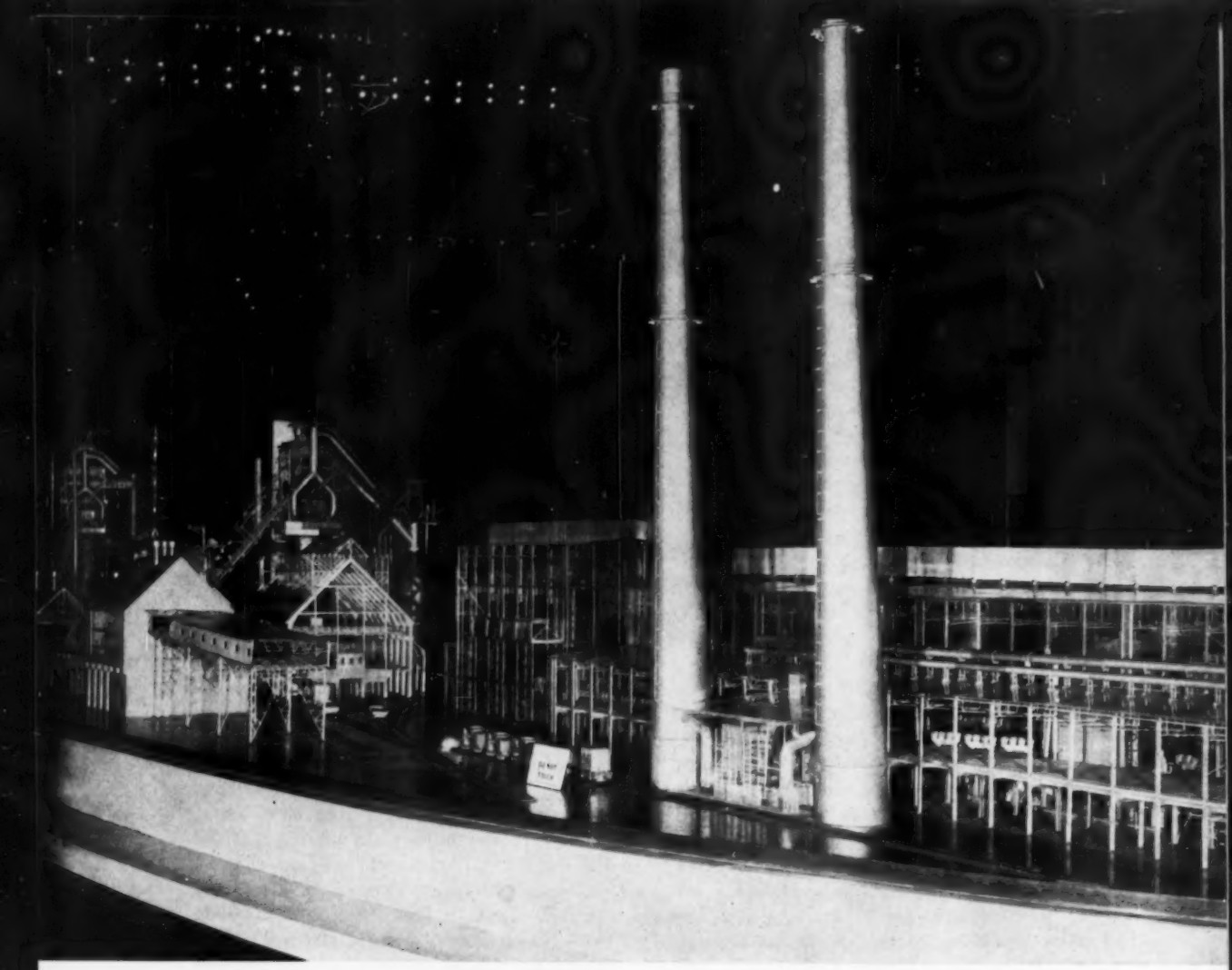
In addition, we cast some nodular iron at the Trafford foundry. The composition was the same as that of the base plates except that the magnesium content was increased to 0.12% to insure that graphite on the welds would be completely nodular. Welds made with this rod were also free of carbide but the microstructure of the weld metal was primarily pearlitic rather than ferritic.

Since carbide-free welds were obtained with both nodular iron rod and Ni Rod, it is evident that oxy-acetylene welding is a technique which will eliminate the discouraging carbide problem.

Like arc welding, oxy-acetylene welding produces joints in nodular iron with strength comparable to that of the base metal. The ductility of oxy-acetylene welds is somewhat higher than that of unannealed arc weldments (an average bend of 5° occurred during root bend tests). More significantly, the bending was not confined to the weld metal. Instead, bending also occurred across the fusion lines and heat-affected base metal. Thus, the lack of fusion-line carbide allows uniform ductility across the weld zone.

Though this was encouraging, another problem developed. Charpy specimens, machined from the weld joints of several samples, revealed that the nil-ductility transition temperature of welds made with Linde rod is only slightly below room temperature, and the transition temperature of welds produced with Trafford rod is above room temperature. Thus small defects may trigger premature failures.

At the present time, while the carbide problem has been eliminated, the problem of high transition temperature remains. This problem must be eliminated before oxy-acetylene welding may be recommended for general use in joining nodular iron. Such weldments may be used, however, if the design stress is low enough to insure that the yield strength is not exceeded (even in the vicinity of stress-raisers), or if adequate inspection can insure freedom from defects which may act as severe stress-raisers. Oxy-acetylene welding may be particularly useful in the future for repairs in noncritical areas where postweld annealing is not permitted.



A Visit to the Soviet Exhibit in New York

*By ARTHUR B. TESMEN**

WHILE THE SOVIET EXHIBITION in New York stressed general technological and cultural advances – such diversified items as sputniks, a fashion show, the atomic icebreaker "Lenin", an assortment of vodkas and foods, the latest methods of cancer research, and a "model apartment" were featured – there were displays devoted to metal production and working. Exhibits included elaborate models of plants and actual working equipment. Russian metallurgists and engineers were on hand to talk about the equipment and technological advances in the U.S.S.R.

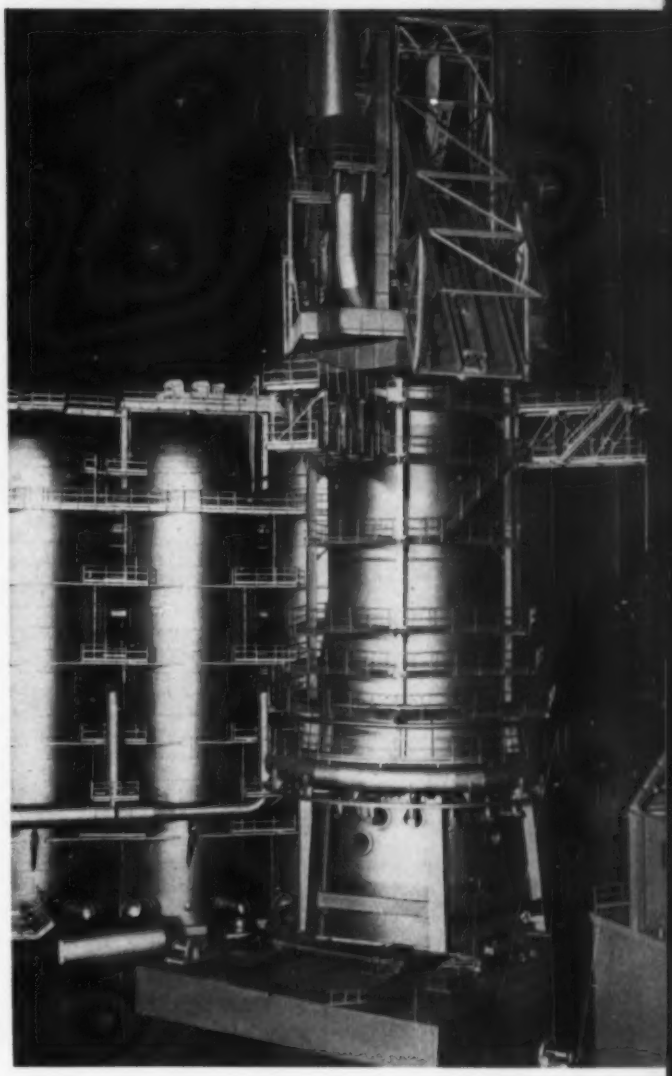
Iron and Steel

A 30-ft. long model of an iron and steel plant demonstrated Russian achievements in iron and steelmaking. Illustrated by Fig. 1, this model represents such iron and steel works as Magnitogorsk and Kuznetsk Metal Combines, and

*Metallurgical Engineer, Loewy-Hydropress Div., Baldwin-Lima-Hamilton Corp., New York. Consulting Editor, *Metal Progress*.

Fig. 1 — Model of Modern Steel Plant Typical of Those Being Built in the Soviet Union Today. According to report, many operations in these newer mills will be completely automatic. Large productions will be achieved by 4500 ton per day blast furnaces which will supply hot metal for 550-ton openhearths and 200-ton electric furnaces

Fig. 2 — A Striking Innovation in Blast Furnace Rebuilding. From one to two months is saved by building the new furnace next to the old one. After the replacement is erected, the old furnace is shut down and dismantled. Little production time is lost in sliding the new furnace into position



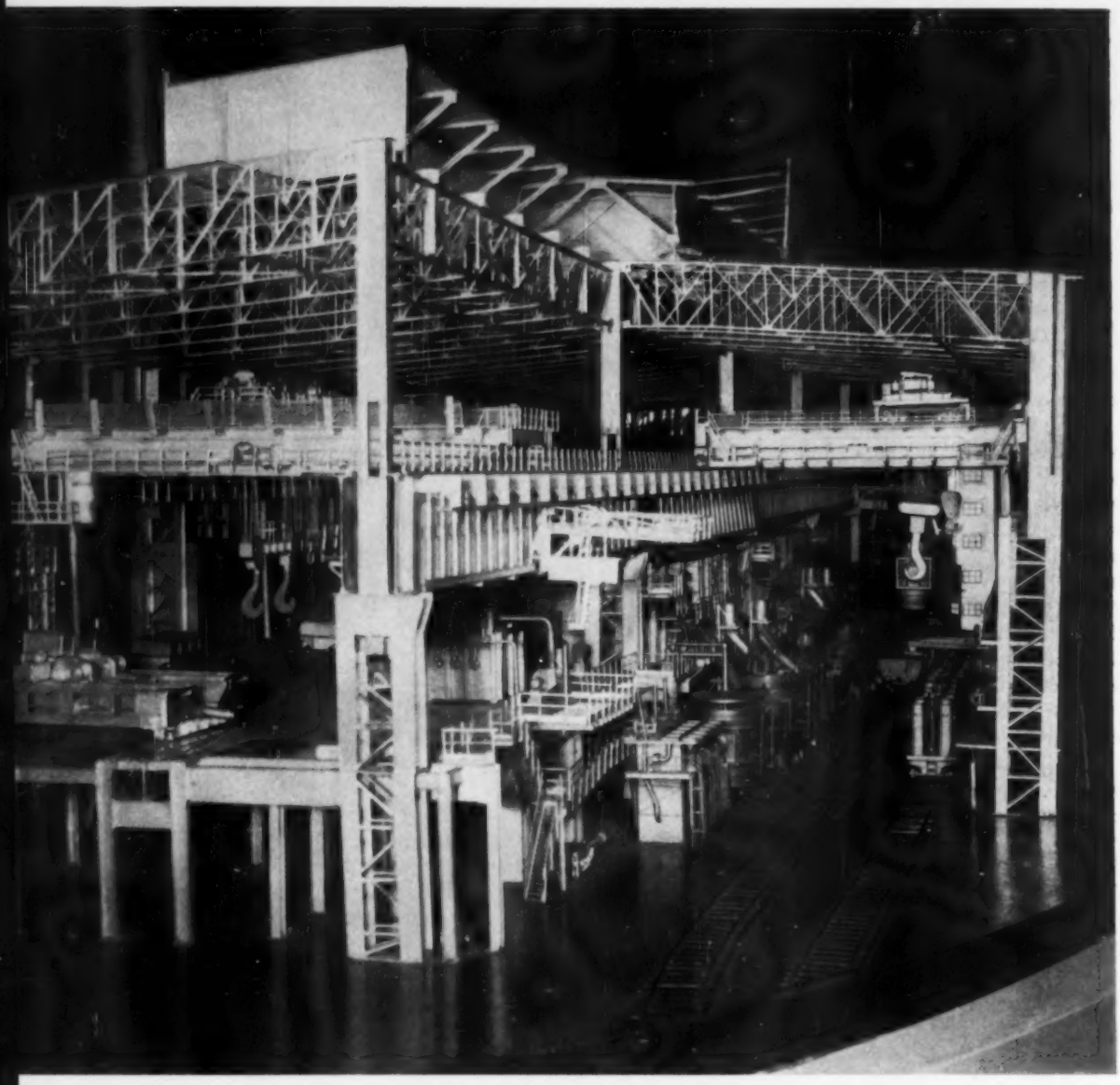
other large mills in operation or currently under construction.

In future blast furnace plants, stove changing will be completely automatic, and blasts of 1800 to 2000° F. will be obtained. Additional moisture and oxygen will be used in the blast, and natural gas, fuel oil, or powdered coal will be injected through the tuyeres. Furnaces capable of 4500 tons per day will be built, according to the Russians. Several furnaces for 3500 ton per day production are already under construction. The 4500 ton per day furnace of special design is intended to increase productivity per worker by 33% and decrease production cost by 5%, compared with the 3500 ton per day furnace.

Current and future furnace construction stresses automatic operation. Automatic skip charging permits flexible control of the skip interchange during one feed, as well as alteration of feeds in one cycle. Transition from charging the furnace periphery to charging the center of the furnace is also automatic. A programed control regulates the skip charging sequence, skip delivery to the main hoist, action of the large and small bells, and operation of the charge distribution. It also receives and transmits the impulses for charging of nonprogramed skips containing coke, flux, or ore to the system. The instrument panel of the charging system indicates and records the charge level, the speed of charge descent, and the rotation of the charge distributor. Automatic equipment to control hot blast temperatures, blast moisture content, top pressures, stove temperatures, air-to-gas ratios, and gas pressures is in wide use.

An electronic computer automatically solves material and thermal balance equations to determine carbon consumption and iron output. The trend is toward combining separate controls into a single system. In the event of failure, preset

Many technological innovations were featured at the recent Soviet Exhibition. The show included elaborate models of Russian steel mills and continuous casting machines, and demonstrations of electroslag and magnetic "walking" welding machines. Also shown was an interesting method for building large gas tanks with huge sheets of plate prewelded in the shop. (D-general; K-general)



values of temperature, moisture content, and blast volume will adjust automatically to restore normal conditions.

Figure 2 illustrates a novel method for rebuilding furnaces which is claimed to shorten the time by a month for small furnaces and by one and one-half to two months for larger furnaces. Conventionally, the furnace is shut down, cooled, dismantled, and then a new furnace is erected in its place. In the Russian method, furnace components are assembled and the new furnace erected a few feet away, while the old furnace is still in operation. The old furnace is then disassembled, and the newly erected one is slid into its place.

Soviet steelmaking plans, which call for 70 million tons of ingots by 1960, 100 million by 1965, and 125 million by 1975, are based upon the construction of a number of 550-ton openhearths, 200-ton electric furnaces, and technological improvements in the existing steel mills. Automatic measurement and recording of pressures, temperatures, and air and fuel flow rates have been introduced in many plants. Some furnaces are

Fig. 3 – Openhearth Shop in Modern Soviet Steel Mill. Most controls are automatic, and double ladle practice is used. For increased production ladles have double stoppers to pour two ingots at a time

equipped with magnetic gas analyzers to determine oxygen in the exhaust gases. Most new installations will have automatic control of furnace pressure, rate of fuel flow, fuel-to-air ratio, fuel and air pressure, and flame reversal intervals.

Fuel-air ratio will be automatically controlled by totaling the fuel input to produce an impulse proportional to the furnace thermal load. Air and oxygen input are also totaled, and the impulse proportional to this sum is automatically compared with the total thermal load by the combustion controller. Impulses generated by temperature differences within the air checkers automatically control the flame reversals; hydraulic or electric devices on the stack or draft fan dampers control the furnace pressures.

Impulses (governed by melting periods and furnace roof and checker temperatures) automatically regulate the furnace thermal conditions and fuel input. One such system presets the durations of the melting periods and the combustion program on a special relay, and signals the timing of each phase. When tapping begins, the program is automatically switched to "tap" by an impulse from a thermocouple located in the furnace spout.

This system will maintain furnace thermal loads at maximum predetermined levels during the charging and heating periods, and will automatically set the thermal loads during the liquid metal addition, melting and finishing periods, in accordance with the heating rate of the air checkers. This will prevent overheating the furnace roof, stabilize air input, and keep gas consumption at economical levels. After tapping, the program control is restored to its "charge" position by an impulse from a thermocouple located at the tap hole.

As for oxygen, only the Zaporoshstal and Dneprospetsal Steel Works are equipped for full use of the gas in iron and steelmaking. However, the seven-year plan includes equipment for oxygen (and natural gas) injection through the blast furnace tuyeres. According to this plan, 40% of all openhearths will eventually have oxygen roof lances and air enrichment by oxygen. Figure 3 illustrates a model of a Soviet openhearth plant.

Figure 4 illustrates a model of a continuous steel casting unit to be installed at the Stalinsk

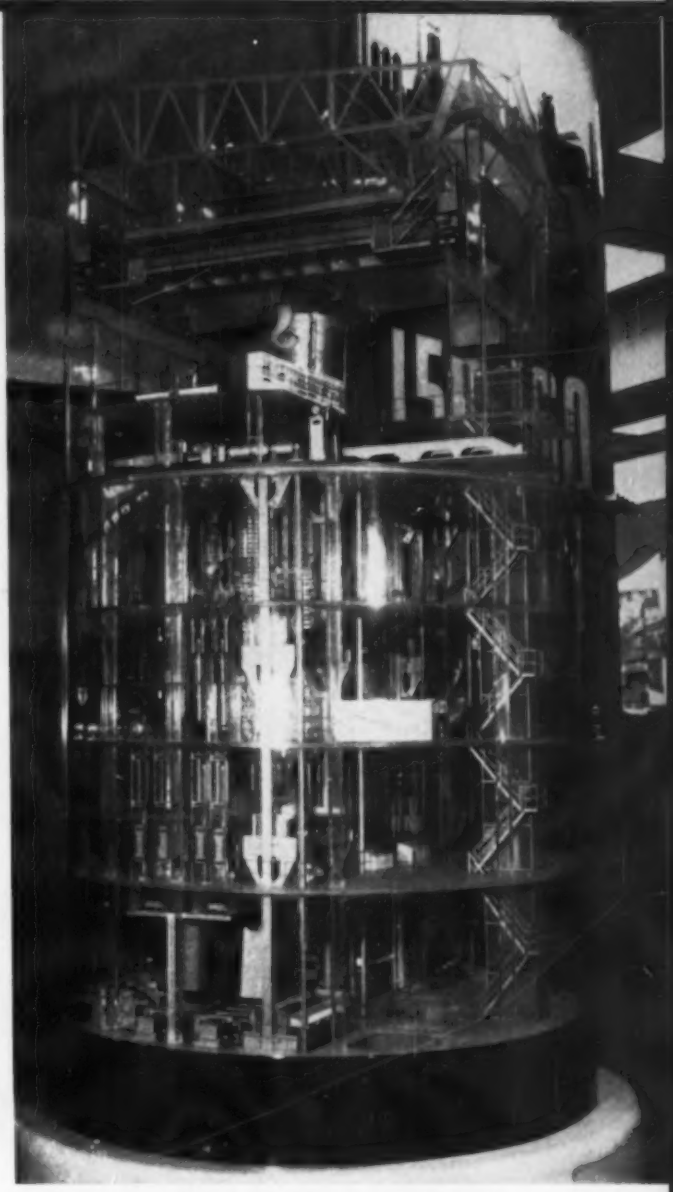


Fig. 4 – Model of Continuous Casting Installation. Designed to cast 500,000 tons of steel per year, this unit is said to be the largest in the world. This four-strand system uses hydraulic drives, and is controlled by pushbuttons. Two such installations are scheduled for operation this year, and 20 are to be completed by 1965

Steel Works in Donbas. It is expected to be the largest in the world. A. I. Osipoff (Central Institute for Research in Ferrous Metallurgy, Moscow) told me that today the largest current installations are those of Atlas Steels Ltd., which casts from a 35-ton ladle, and the Soviet "Krasnoye Sormovo" Works, which casts two strands from a 50-ton ladle. The Stalinsk machine will cast four strands simultaneously from a 140-ton ladle into slabs of 6 × 24 in. to 8 × 47 in. in

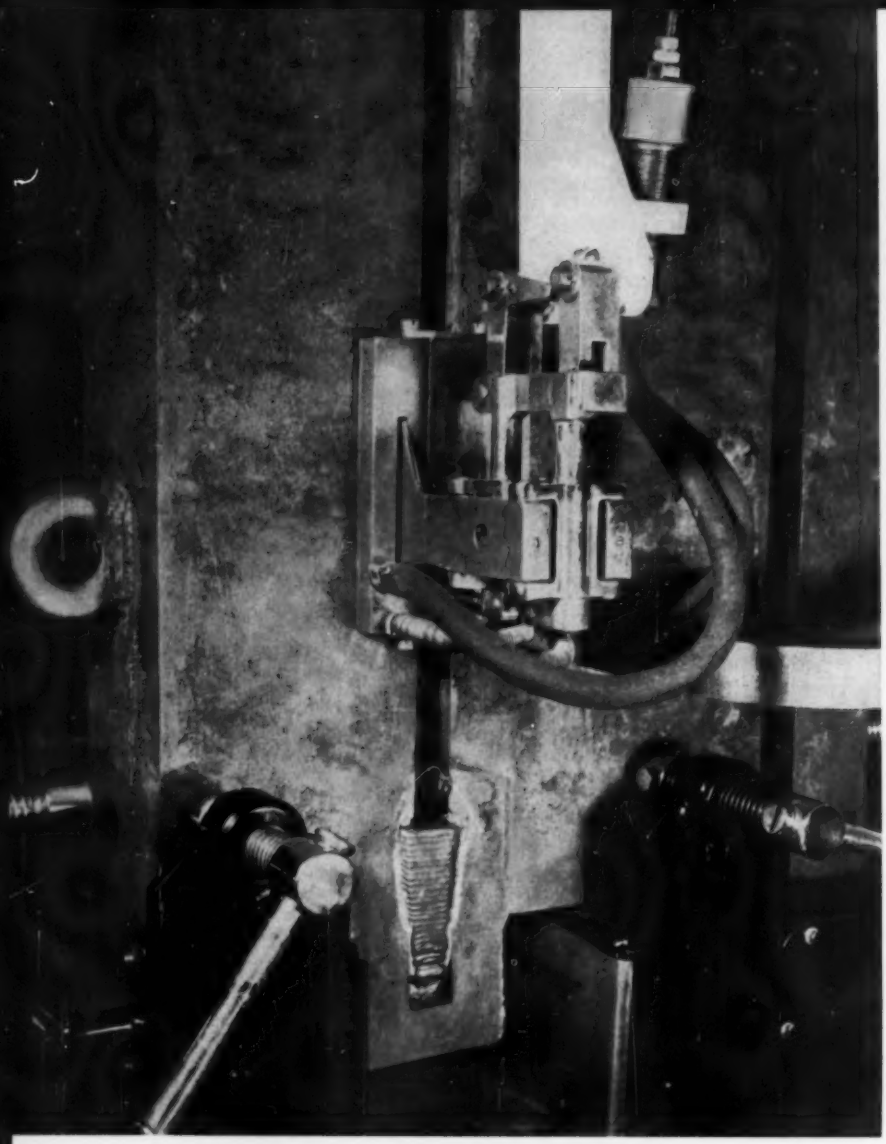


Fig. 5 — This Is the Welding Head of an Electroslag Welding Machine. The start of a weld in thick plate is shown. According to the Russians, this machine can weld parts up to 60 in. thick in one pass. Speed of welding depends on thickness of parts to be welded; it ranges from 1.3 to about 30 ft. per hr. Soviet engineers use this process widely in making heavy items such as turbine shafts, press frames, and anvils for forging hammers. Great economies are reported

cross section at rates of 0.2 to 5 ft. per min.

Among the special features of this unit are wide use of hydraulic (rather than electric) drives and a single withdrawing stand. "Dummy" bars for starting are fed from the bottom. The secondary cooling zone is 36 ft. high, and the total height of the unit is 115 ft., with 90 ft. in an underground pit of precast reinforced concrete pipe. Its maximum capacity will be 500,000 tons of sheet rolling slabs per year.

As to operation, metal from the 140-ton ladle is poured into two intermediate ladles, 14 tons each, and then into slab molds, 5 ft. long. The molds consist of an inner copper and outer cast iron plate bolted together. To decrease the clearance between the mold walls and the slab, the walls are designed in the shape of an inverted cone. The mold is lubricated by an automatic system which feeds mineral oil to the inner wall.

The slab is directed by a system of rollers, 4 in. in diameter, through a distance of about 35 ft. About 1 to 4 cu.in. of water is used per pound of slab throughout the secondary cooling zone. This is calculated to maintain the slab surface temperature above 900° C. (1650° F.) to prevent surface cracking. Slabs are cut into 13 to 17-ft. lengths by a hydraulically operated oxy-gas torch. The entire operation is automatically or pushbutton controlled, as required, f a pulpit. This pulpit is also equipped with telephone and loud-speaker signalling and with television observation at each floor level.

According to Mr. Osipoff, two such installations are scheduled for operation before the end of this year. Also, a total of 20 units of various capacities are to be completed during the seven-year

Fig. 6 – "Walking" Welder Making a Corner Weld. Two magnets connected by an electric cam comprise the walking mechanism. The magnets pull upward with a force of 330 lb., and assure constant contact with the workpiece. This portable machine welds corner, "T" and butt joints with thicknesses from 1 to 4 in.

plan. One of them will operate in conjunction with a planetary rolling mill.

A Russian innovation which has received much attention since its recent announcement is electroslag welding. As described in *Metal Progress*, January 1959, p. 80, the method is "an arcless method for welding large parts". Heat for fusion is derived from electrical resistance of the slag rather than an arc, open or submerged.

In the Russian show, two electroslag welding machines equipped for "live" demonstration were exhibited. The A-372-P model, shown in Fig. 5, operates on alternating current at 1000 amp. with a maximum of 56 v. It uses wire up to about ⅛ in. diameter, according to I. V. Novikov*. This welder, which weighs 700 lb., can join parts up to 60 in. thick in one pass. It operates at 1.3 to about 30 ft. per hr. depending on thickness.

The magnet-walking welder, shown in Fig. 6, is a portable unit for vertical corner joints (with or without preparation) and for "T" and butt joints with thicknesses of 1 to 4 in. Operating on direct current at densities up to 750 amp., it uses wire about 3/32 in. in diameter. It weighs 55 lb., and its vertical rate of travel is 3 to 30 ft. per hr., depending upon the type of joint. The "walking" mechanism consists of two magnets connected by an eccentric cam. These magnets pull with a force of 330 lb., and assure constant contact with the workpiece. Movement of the welder along a corner or a "T" joint is automatic. Joint surfaces serve as guides and tracers for the magnet mechanism and the welding head. The weld itself is molded by a copper plate which

*Welding Engineer, Paton Electric Welding Institute, Kiev, where the process was developed.

moves with the welder on one side, and a moving or stationary backer on the root side. Thirty heavy machinery, pressure vessel, and hydroturbine manufacturing plants have adopted this method.

One of the largest users of electroslag welding, Novo-Kramatorsk Heavy Machinery Plant, studied the economics of the process. It is difficult and time-consuming to make large forgings and castings. Also, much metal is expended. For example, large hydraulic turbine forgings may require ingots weighing three times the finished part. For a large press crosshead of 160 tons (rough machined weight), 240 tons of liquid steel may have to be poured.

The study proved that electroslag weldments save weight and reduce metal consumption. In fact, 128 tons of castings and over 300 tons of forgings were saved yearly because of the simplified design of smaller components used together with plate in electroslag weldments. Substitution of plate weldments for large integral forgings and castings resulted in yearly savings of 73,250 man-hours by eliminating molding, casting and rough machining. (However, this saving is partially offset by the need for stress-relieving the entire weldment.)

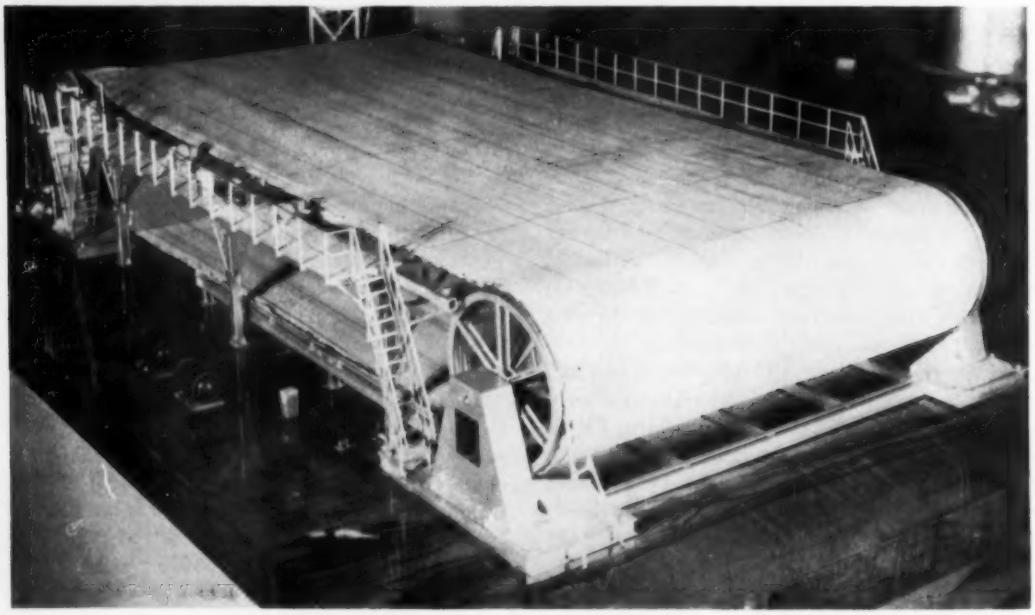
Machining is reduced if plate and comparatively small cast and forged components are used; many surfaces do not require finish machining. Casting and forging allowances can also be reduced. When these methods were tried in producing a 4000-ton press frame, 624 machine-hours were saved. Over-all production cycles were cut, since smaller components could be fabricated simultaneously.

To sum up, the electroslag process saved a total of 5173 man-hours, 16.5 tons, and 98,000 rubles in producing a series of 4000 and 6000-ton mechanical forging presses in one year.

Another accomplishment of electroslag welding: In welding an 88-in. O.D., 13.4-in. wall thickness hydraulic cylinder, ingot weight for the shell was reduced from 210 tons to 125 tons, with a corresponding reduction of 22 working days and 350 man-hours. Similarly, an ingot weight requirement for a large hydroturbine shaft was reduced from 120 to 70 tons with a 38% reduction in machining costs.

Electroslag welding has effected savings in the welding of other large parts. These include hydroturbine shafts (they can be assembled from separate forgings which are subsequently welded together), press frames and crossheads, anvils for counterblow hammers, generator stands and housings, and boiler drums.

Fig. 7 – This Is a Major Step in an Unusual Method for Prefabricating Large Tanks. Special positioners hold plates and sheet in place for welding. When the sheet weldment is large enough, it is rolled into a cylinder for easy transportation to the site. Fig. 8 shows erection



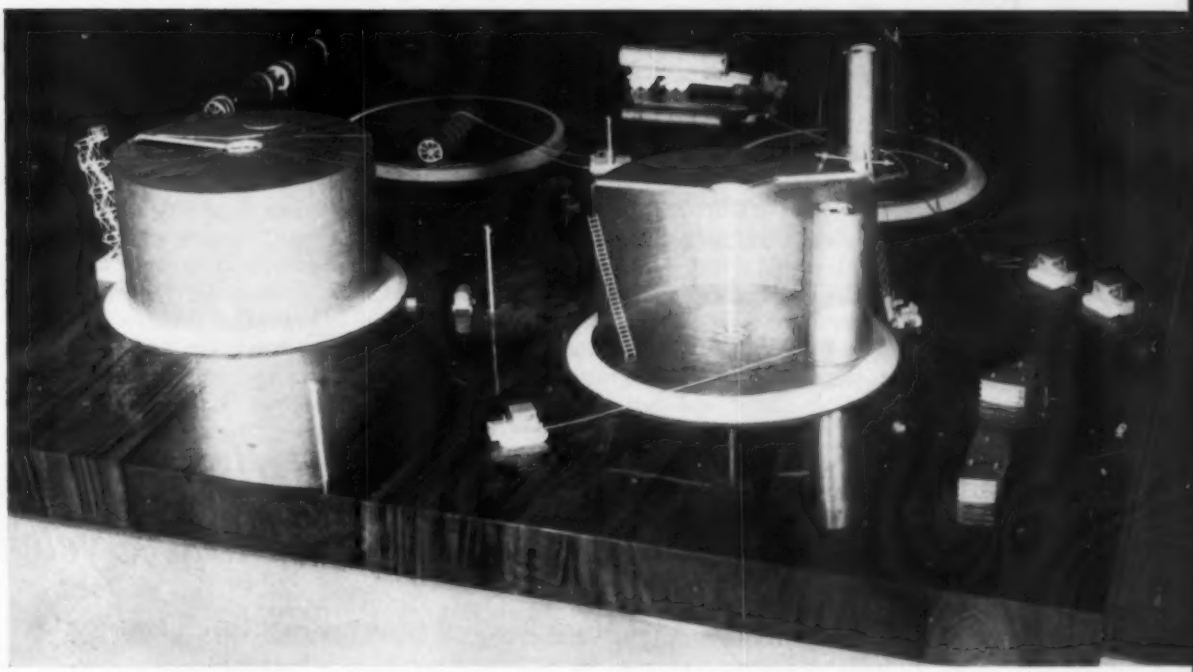


Fig. 8 – Transportation, Erection and Field Welding of Tanks. In the rear, cylinders of rolled-up plate (see Fig. 7) are being carried, stored, or readied for tank construction. Two stages of the fabrication are shown in the foreground. As can be seen, the cylinder is gradually unfurled while flat plates are welded to form the top. The tank is finished when the cylinder is completely unrolled and the edges are welded. Tanks can be built in one fourth to one fifth the time needed for conventional methods, according to reports

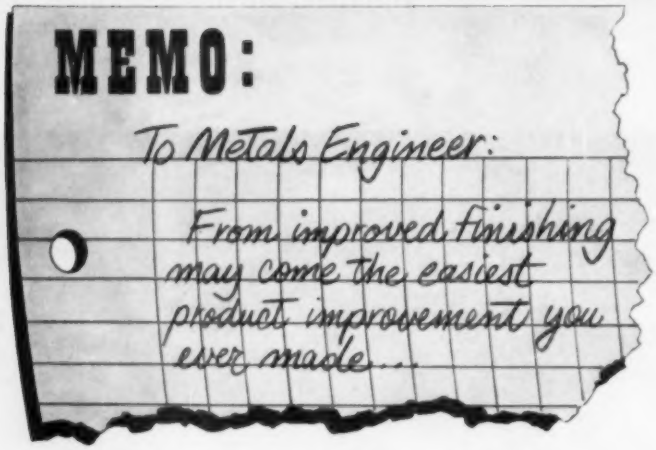
Featured in the exhibit was an interesting method for reducing field welding costs by shop prefabrication. As shown in Fig. 7, plate and sheet weldments for tanks are automatically welded in a shop. Special positioners hold the plate in place. The welded sections are then rolled up for easy transportation to the site. There, they are unwrapped and erected (see Fig. 8). Only a minimum of welding remains to be done in the field. The method is claimed to reduce construction schedules four to five times.

The Russians also displayed an electric impulse machine for cutting impressions in heat resistant metals and high-alloy steels of very high hardness. It operates from a 28 kw. motor generating about 400 impulses per sec. Metal can be removed at about ten times the speed attained by electric spark machining. The machine operates at five ratings from 5 amp., 8 to 10 v., to 230 amp., 32 v. Maximum depth of penetration is about 6¼ in., and it will cut about 0.33 cu.in. per min. of hard material. It is claimed to produce a surface finish superior to that of electric spark cutting.

An impressive illustration of Soviet manipulative technique was shown in the machine developed for encasing ultra-fine metal wire (2 to 100 micron diameter) in glass. A high-frequency coil heats the end of a high-temperature glass tube in which a ball of metal – copper, steel, cast iron, silver, tin, germanium, or another – is inserted. The ball of molten metal, covered by glass, remains suspended in the tube end. A filament of molten metal and glass is drawn out of the tip of the tube and caught on a rotating spool.

By maintaining the proper spool speed and temperature, a filament of metal wire encased in a glass insulation can be continuously drawn and wound. A guide die is used below the tube end. Production speed is said to be 1000 ft. per min., and the machine is equipped with an automatic device for measuring length.

Other items of interest to metallurgists included a model of a ladle degassing unit, a programed resonance testing machine for bending or torsion fatigue tests, a plastic deformation machine, and an electron microscope (250 to 150,000 magnifications, 15 angstrom resolution).



No. 3 in a Series on Better Finishing

Alkaline Cleaning of Metals

Part I—Cleaner Formulations and Cycles

By the A.S.M. Metals Handbook Committee on Alkaline Cleaning

A variety of practices are followed in soak, spray and electrolytic cleaning of metals with alkaline solutions. This article describes methods, cycles and formulations. A second article in *Metal Progress* next month will deal with equipment requirements, maintenance schedules and operating costs (L12k)

THE CLEANING ACTION of the alkaline bath depends to a great extent on the detersive properties of the solution. Agitation of the bath and movement of the parts through it are a secondary, although important, factor in removing soil.

Unless the soil is easily removable, **soak cleaning** is slower and less efficient than spray and electrolytic methods. Generally it is employed for moderate and small volumes of work. The basic cycle for the soak method is given in Table I.

Spray cleaning combines the advantages of the detersive properties of the solution with the impinging action of sprays, which loosen the soil mechanically and therefore provide greater efficiency than the soak method for removing tenacious soils. However, because of foaming problems, spray cleaners have lower detersive properties than soak cleaners. Since spray cleaning requires a greater investment for equipment than the soak method, a greater volume of work is needed to justify the higher cost. See Table I for the basic cycle. Design of the part must be such as to allow the spray to reach all surfaces.

Electrolytic cleaning gives the cleanest surfaces obtainable from conventional alkaline methods. The resulting surfaces are suitable for the most exacting plating requirements and for subsequent finishing operations on close-tolerance parts. The effectiveness of this method results from strong agitation of the bath by gas evolution and oxidation-reduction reactions during electrolysis. Another important factor is that similar electrical charges are imparted to certain dirt particles and the work, causing the dirt to be repelled from the work surface. Table I gives the basic cycle for the electrolytic method.

In **barrel cleaning**, parts too small for racking and in quantities too large for handling in baskets are given essentially the same cleaning as by the soak method except that agitation is supplied by a rotating barrel. A barrel cleaning line should have at least two cleaning tanks. The first stage removes the gross soil from the parts. This

permits the subsequent stage or stages to operate more effectively in a comparatively unpolluted solution.

Steam gun cleaning is used mostly on machinery and other bulky objects too large for soak tanks and spray washing machines. It is suitable for cleaning steel and, with a mild alkaline cleaner, for removing oil and dirt from painted and aluminum surfaces. Other applications include maintenance of screens on paper pulp machines, buffing machines or other equipment that is immovable or bulky, and of large production parts in a volume too low to justify the cost of mechanized cleaning equipment. The alkaline solutions used on steel surfaces may be strong in caustic soda with additions of orthosilicates, whereas those used for cleaning painted surfaces and aluminum must be very low in alkali to avoid harming the paint and to prevent etching the aluminum.

Spray-rotary washers are suitable for removing cutting and drawing oils from small and medium stampings and from small machined parts such as nuts and bolts. The advantage of these washing machines is their efficient processing of large quantities of small irregularly shaped parts, since cleaning is done in a drum that rotates in the spray of cleaning and rinsing solutions. Cleaned parts may be treated for short-time rust protection, as for in-process operations, by the addition of rust inhibitors to the rinse preceding drying. Alkaline cleaners with good wetting and low foaming characteristics are recommended.

Spray-rotary brush washers are employed for cleaning flat sheet, panels, coil stock, and steel

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This article was prepared for the forthcoming 8th edition of the Metals Handbook. About the time the author committee finished its work, it was decided that the new Handbook would be published in five volumes, with all coverage of processes deferred for the second volume. In order to make the information on alkaline cleaning available without a delay of two or three years, this article, in two parts, is being published in this and next month's issue of *Metal Progress*.

This article on alkaline cleaning was prepared as a model for other Handbook articles on metal cleaning and finishing processes. The other articles have not been started, and, consequently, comments and suggestions from readers are invited. They will be helpful in planning the remainder of the Handbook coverage on metal cleaning. Your comments may be directed to the Editor of Metals Handbook, at ASM's new headquarters, Metals Park, Novelty, Ohio.

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Table I – Basic Cycles for the Principal Alkaline Cleaning Methods

Variable	Cleaning Method		
	Soak	Spray	Electrolytic*
Cleaning			
Time	3 to 5 min.	½ to 1	½ to 1
Temperature	160 to 212° F.	130 to 170	160 to 210
Concentration	4 to 8 oz. per gal.	¼ to 1½	4 to 8
Unheated Rinsing			
Time	¼ to ½ min.	to ¼	¼ to ½
Temperature	Not heated	Not heated	Not heated
Hot Rinsing			
Time	½ to 2 min.	to ¼	½ to 2
Temperature	160 to 200° F.	130 to 160	160 to 200
Hot Air Drying			
Time	1 to 3 min.	½ to 1	1 to 3
Temperature	160 to 220° F.	160 to 220	160 to 220

*Usually preceded by soak or spray cleaning. For some severe applications, soak and electrolytic cleaners contain up to 12 oz. per gal. Electrocleaners are seldom operated below 180° F.

blanks to remove soil and mill dirt prior to the application of soap coatings (which are later removed in spray cleaners) for metal drawing and forming operations. Mild alkaline cleaners with good wetting characteristics and foam suppressors are usually satisfactory.

The selection of a cleaning method is most often dependent on the volume of work to be processed. When high work volume is expected, spray cleaning is chosen because large quantities can be processed rapidly. Soak cleaning is appropriate for low volume. If the cleanliness is the governing requisite, electrolytic cleaning is selected. When both factors are equally important, preference is generally given to cleanliness.

Soak and spray cleaning can be used independently of each other or of electrolytic cleaning, but the latter is used to best advantage in combination with either the soak or spray methods. By preceding the electrolytic cleaning with soak or spray cycles to remove gross soil, a longer period of usefulness is obtained from the electrolytic solution.

Examples of typical cleaning jobs by each of the major alkaline methods are given in Table II. The sequence of cleaning operations for typical subsequent treatments is shown in Table III.

Types of Soil

The soils encountered in metal cleaning are of three types – oily, semisolid and solid.

Oily soils include mineral oils, fatty (vegetable and animal) oils, dried emulsion residues of mill oils, light oil-base rust preventives, and compounded cutting and grinding oils. Mineral, vegetable and animal oils are used in many machining operations. Removal of these follows machining and precedes inspection, subsequent machining, assembly, or oiling prior to storage.

Cutting and grinding fluids are usually of the soluble oil type. As with mineral oils, the removal of cutting and grinding fluids is mainly in-process cleaning – that is, prior to inspection, additional machining or assembly. The detergency of the cleaner need not be so great as for unemulsified oils.

Semisolid soils include greases, waxes and tars, heavy rust preventives, animal and vegetable waxes and fats, and metallic soaps. Mineral greases and fats are often components of polishing and buffing compounds. Cleaning will be that required prior to plating or anodizing.

Solid soils are grinding and polishing abrasives and grits, dried pigmented drawing compounds, baked or carbonized oil films, solder fluxes, graphite, and metal oxides. They are removed by one or more of the following mechanisms:

1. *Saponification* – Animal and vegetable oils may be partially removed by this reaction, but saponification is slow and usually incomplete.

2. *Emulsification* – This is a mechanism whereby the soil is broken up and suspended in the cleaner in the form of very fine liquid particles.

3. *Dispersion* – By this process the soil is dispersed, thereby lowering the concentration of soil at the surface of the work.

4. *Flocculation or Aggregation* – Once the soil has been removed and dispersed, it should reunite, away from the work, to precipitate out or be skimmed off. The ability of a cleaning solution to perform this function increases its life and produces cleaner work because suspended soil is not redeposited on the work.

5. *Film Shrinkage* – Oil is removed by this method in a series of continuous steps: (*a*) The oil is a continuous layer on the metal surface making a contact angle greater than 90° with the metal. This contact angle is lessened when the metal is acted on by a hot cleaner and eventually the angle diminishes to 0°. (*b*) When the contact angle has reached a very small value, the film is broken up into very fine globules which then

Table II – Typical Alkaline Cleaning Jobs

Work	Production Rate Per Hr.	Soil Removed	Subsequent Operation	Cycle
		Soak Cleaning		
Aluminum, <5 sq.in.	500 to 1500	Machine oil	Assembly	Clean, rinse, dry, inspect and assemble (*a*).
Brass and steel(*b*)	800	Buffing compound	Plating	Clean, rinse, acidulated rinse, rinse, plate(*c*).
		Spray Cleaning		
Steel strip, 6 in.	30 to 40 fpm.	Mill oil	Press work	Clean, rinse, coat with drawing compound.
Steel brake shoes(*d*)	6250	Oil, grease	Phosphating	Clean, rinse, rinse, coat with phosphate(*e*).
		Electrolytic Cleaning		
Steel electrical parts(*f*)	7200	Inert coating(*g*)	Nickel plate	Clean, spray rinse, electrolytic HCl dip, spray rinse, acidulated rinse, spray rinse, nickel plate.
Cast iron frame(*h*)	300 to 600	Shop dirt	Assembly	Clean, rinse, acidulated rinse, rinse, spray rinse, air blow-off, alkalized rinse, dry.
Steel (mounting plates), 30 × 18 × ¼ in.	160	Mill oil	Zinc plate	Clean, rinse, electrolytic HCl dip, spray rinse, electrolytic cyanide dip, zinc plate.
		Soak Plus Electrolytic Cleaning		
Copper-plated steel(*i*)	450	Color buffing compound	Nickel plate	Soak clean, rinse, cathodic clean, rinse, cyanide dip, rinse, rinse, plate.
Steel and iron parts(*j*)	1200	Polishing compound	Copper plate	Soak clean, rinse, anodic clean, rinse, acid dip, rinse, rinse, plate.
Brass (horn button), 9 sq.in.	48 per rack, 1000 per hr.	Buffing compound	Nickel plate	Soak clean, rinse, electrolytic clean, rinse, rinse, acid dip, rinse, rinse, plate.
Steel (stop-light switch housing), 5 sq.in.	1500 per barrel, 4100 per hr.	Drawing compound	Zinc plate	Barrel soak clean, rinse, electrolytic clean, acid dip, rinse, rinse, plate.
		Spray Plus Electrolytic Cleaning		
Steel reflectors(*k*)	900	Light oil	Decorative Ni-Cr	Spray clean, rinse, anodic clean, rinse, rinse, acid dip, rinse, rinse, plate.
Copper-plated steel(*l*)	1200	Buffing compound	Decorative Ni-Cr	Spray clean, rinse, cathodic clean, cathodic clean, rinse, acid dip, rinse, plate.
Copper-plated shells(*m*)	900	Buffing compound	Decorative Ni-Cr	Spray clean, rinse, cathodic clean, cathodic clean, rinse, acid dip, rinse, plate.

(a) 300-gal. tank. *(b)* Polished, 25 sq. in. and smaller. *(c)* 150-gal. tank, manually operated. *(d)* One third square foot area. *(e)* Cleaning zone 26 ft. long, 5 ft. wide, 8 ft. high; spraying zone 24 ft. long; 3300-gal. tank, conveyer speed of 12 ft. per min. *(f)* Relay cores and armatures, ¼ in. thick, 2 in. wide, 4 in. long. *(g)* Used to prevent sticking during heat treatment. *(h)* Compressor main frame, 6 × 2½ in. *(i)* Percolator shells, 10 × 5 in. diam. *(j)* Electric iron covers, 10 × 8 × 3 in. *(k)* Reflector plates, 15 × 15 × 5 in. *(l)* Lawn mower hub caps, 3 in. diam. × ¼ in. *(m)* Steel toaster shells, 8 × 7 × 6 in.

combine to form much larger globules. The large globules are removed from the metal mainly by a combination of low interfacial tension and specific gravity difference.

A universal or all-purpose cleaner is not available because the requirements for various cleaning jobs are too diverse and not mutually compatible. Therefore compromises are made in formulations to fit particular applications.

The cleaning action of alkaline compounds is attributed mainly to the actions of the "builders".* Generally the cleaning compound should (*a*) reduce surface and interfacial tensions, (*b*) produce both active and available alkalinity, (*c*) buffer a highly alkaline solution, (*d*) soften hard water, (*e*) deflocculate, disperse and emulsify removed soils, (*f*) rinse readily, (*g*) be compatible with other builders and stable within themselves, (*h*) be noncorrosive to parts, (*i*) be free-flowing, dustless, and nonhygroscopic.

*The principal bulk components of the formulation are known as "builders". Most are sodium salts which provide alkalinity and other desirable properties at low cost. The important sodium compounds used as builders are carbonates, phosphates, silicates and hydroxide.

Table III – Recommended Sequence of Cleaning Operations for Various Subsequent Treatments

Subsequent Treatment	Sequence of Cleaning Operations
	Steel
Assembly	Soak or spray clean, water rinse, dry.
Phosphating and painting	Soak or spray clean, water rinse, water rinse, phosphatize, water rinse, acidulated rinse, dry, paint.
Plating, chromium (decorative)	Soak or spray clean, water rinse, electrolytic alkaline clean, water rinse, acid pickle, water rinse, electrolytic alkaline clean, water rinse, acid dip, water rinse, plate.
Plating, zinc	Soak or spray clean, water rinse, electrolytic alkaline clean, water rinse, acid dip, water rinse, plate.
Porcelain enameling	Soak or spray clean, water rinse, soak or spray clean, water rinse, acid pickle, acidulated rinse, immersion plate in nickel sulphate, acidulated rinse, neutral dip, dry.
Storage	Soak or spray clean, water rinse, dry, oil.
	Aluminum and Alloys
Anodizing (decorative)	Soak or spray clean, water rinse, bright dip, water rinse, water rinse, anodize.
Painting	Soak or spray clean, water rinse, deoxidize (optional), water rinse, chemical treat, water rinse, acid rinse, dry, paint.
	Copper and Alloys
Plating, chromium	Soak or spray clean, water rinse, electrolytic alkaline clean, water rinse, electrolytic alkaline clean, water rinse, acid dip, water rinse, plate.
	Magnesium (Machined)
Assembly	Soak or spray clean, water rinse, dry.
	Zinc Die Castings
Plating, chromium (decorative)	Soak or spray clean, water rinse, electrolytic alkaline clean, water rinse, acid dip, water rinse, electrolytic alkaline clean, water rinse, acid dip, water rinse, plate.

By reducing the surface and interfacial tensions, a cleaner can get under the soil more easily. It will wet or replace the soil, thereby producing a cleaning action. However, a given builder cannot be expected to decrease effectively the interfacial tensions of all types of soil.

A cleaner must provide active as well as available alkalinity because most soaps and synthetic detergents are more efficient at pH values between 7 and 13. High alkalinity is required for saponification reactions. All water-soluble salts of strong bases and weak acids that ionize meet this requirement. The salts must dissociate to a considerable degree to produce an abundance of active alkalinity. At the high concentrations used in cleaners, most do not ionize 100%.

The active alkalinity is the important or working alkalinity for high detergency. It is continually being lost through reactions such as saponification and neutralization, and by drag-out. This causes the available alkalinity to ionize, thus maintaining the level of active alkalinity. Buffers tend to preserve the original pH of a solution when an acid or base is added to it. The amount of buffering action and available alkalinity in a cleaner are factors that will give long life to a cleaner at a constant pH.

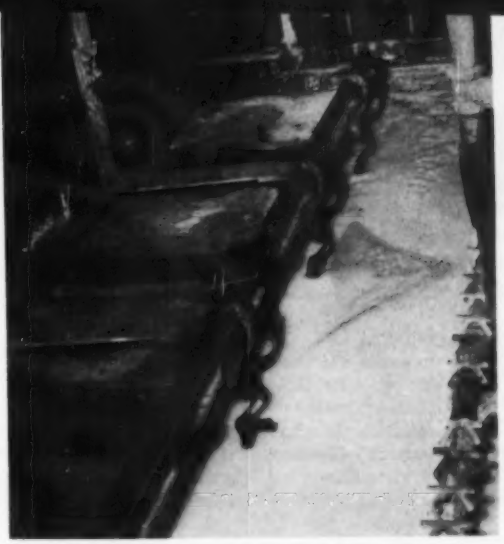
Hard water used with cleaners must be treated to prevent formation of insoluble calcium, magnesium and iron soaps, which cause "scaling-up" of equipment and inactivation of builders or soaps intended for other functions. The contained calcium, magnesium and iron can be rendered inactive by adding a builder specifically designed for this purpose as well as one that will provide active and available alkalinity, or both.

An alkaline soak cleaner must disperse soil once it has been removed from an object; otherwise the solution in the immediate vicinity would become highly contaminated and increase the likelihood of resoiling the part during its removal. Redeposition of the soil can be prevented by dispersion, emulsification, precipitation or flotation. If a soil is emulsified, the emulsifying agent should be capable of holding the emulsion at low concentrations, which results when some of the emulsified soil is carried into the rinse tank. If the emulsion breaks easily on dilution, as many do, the object will be resoiled in the rinse. An efficient cleaner will prevent resoiling.

All builders must be readily soluble in cold water, with no significant affinity for the object being cleaned. Traces of cleaner that remain on the work after rinsing may cause health hazards such as dermatitis or create production problems such as peeling or blistering of paints and electrodeposits. Most builders will rinse easily.

The builders must be stable within themselves and not adversely reactive with each other. The lack of these requirements would result in cleaners dangerous to handle because of heat released from spontaneous reactions. Inefficient cleaning due to inactivitation of essential builders may also occur. Generally builders that are neither oxidizing nor reducing are compatible with each other. Because of their low cost, sodium salts are most frequently used together to provide a common cation. The combination of common cation and poor oxidizing and reducing ability provides compatability.

For ease of handling and economy, all cleaners should be relatively free-flowing, dustless, and should not absorb excessive amounts of water. A cleaner that cakes is costly in labor time spent preparing it for use. A dusty cleaner would be harmful to the operator charging it into the tank or, when dry, it may stratify during shipping with the dense builders sifting to the bottom of the container. This could result in an improperly formulated cleaner if the contents of the entire package were not added to the tank at one time. A hygroscopic cleaner, shipped in a cardboard carton, becomes wet from moisture absorbed from the atmosphere and will soon leak through the container. Once a cleaner has become soupy, it cannot be safely handled and stored or added accurately to a tank. Some of the best builders are relatively hygroscopic but can still be used if other builders are added to counteract this property. A cleaner of this type holds some moisture. It feels damp but is not wet.



Electrolytic Cleaning Does the Best Job of Cleaning Parts for Electroplating. Alkaline detergent must give a highly conductive solution and provide a foam blanket strong enough to prevent alkali misting without danger of explosion. (Courtesy Oakite Products, Inc., New York)

Special Requirements

For soak and spray cleaning, certain characteristics are needed in addition to those just discussed. The cleaner should (*a*) be soluble or colloidal, (*b*) contain sufficient sequestering agent*, (*c*) saponify animal and vegetable oils and greases or emulsify unsaponifiable (mineral) oils, (*d*) neutralize acid soils and fluxes, and (*e*) clean in reasonable time. Compounds used in solutions for spray cleaning must not cause excessive foaming.

The requirements for solutions used in electrolytic soak cleaning are essentially those of the spray and soak cleaners, except that they (*a*) must not contain soaps, wetting agents or colloids that deposit on the work or decompose under electrolysis or heat, (*b*) must be highly conductive, (*c*) form a fine, rapidly breaking foam that suppresses alkali misting (heavy foam is hazardous due to the entrapment of an explosive mixture of hydrogen and oxygen liberated during electrolysis), and (*d*) contain no chlorides or other ions that attack the anode or cathode.

Composition of Cleaning Solutions

Water is the most important component in an alkaline cleaning solution. The detergency of hot water alone is often adequate. Water transmits the heat and agitation evenly to the work to reduce the viscosity of the soil, thus removing at least part of it. It is the water which carries the ingredients of the cleaner to the work, flushes the work and carries away the soil.

Alkaline cleaners are formulated to improve the action of the water. The principal bulk components of the formulation are the builders, which provide alkalinity and other desirable properties previously described. The important sodium compounds used as builders are carbonates, phosphates, silicates and hydroxide.

Carbonates such as soda ash or sodium carbonate serve as buffers, as low-cost sources of alkalinity, and as water softeners. Sodium carbonate is by far the most important of the carbonates in metal cleaners. The carbonates are poor cleaners, but supply a fair amount of alkalinity. A 1% aqueous solution, for example, gives a pH of 11.5. Because of its low cost, sodium carbonate is widely used as filler material in trade-name cleaners where price is important. However, the real value of carbonates is in helping to keep compounded cleaners dry and free flowing. This is especially important for cleaners containing a large amount of caustic soda. Carbonates may change the detergent ability of a formulated cleaner by slightly decreasing the pH, such as from near 14 to below 13.

Sodium bicarbonate or sodium sesquicarbonate, or combinations of the two, are used as builders in cleaning solutions in which it is desired to buffer the pH at a low level of alkalinity. The modified alkalinity makes such a cleaner safe for use on painted surfaces and on metals such as aluminum, copper and zinc which would be adversely affected by strong alkalis.

*A sequestering agent is a material that combines with metallic ions to form water-soluble complex compounds.

Table IV – Typical Alkaline Cleaner Formulations for Various Metals

	Aluminum		Copper			Cu plate	Iron and Steel		
	Soak	Spray	Soak	Spray	Electro-lytic	Electro-lytic	Soak	Spray	Electro-lytic
					Composition of Cleaner, % by Weight				
Builders									
Sodium hydroxide, ground	—	—	20	15	15	55	20	20	55
Sodium carbonate, dense	—	—	18	—	—	8	18	29	8.5
Sodium bicarbonate	21	24	—	34	34	—	—	—	—
Sodium tripolyphosphate	30	30	—	—	10	—	20	20	10
Tetrasodium pyrophosphate	—	—	20	10	—	10	—	—	—
Sodium metasilicate, anhydrous	45	45	30	40	40	25	30	30	25
Surface active agents (wetting agents)									
Sodium resinate	—	—	5	—	—	—	5	—	—
Sodium alkylaryl sulphonate	3	—	5	—	—	—	5	—	1
Alkylaryl polyether alcohol	—	—	2	—	—	1	2	—	—
Nonionics high in ethylene oxide	1	1	—	1	1	1	—	1	0.5
					Other Conditions				
Operating temperature of solution, °F.	160	160	180	170	160	180	200	170	180
Concentration of cleaner, oz. per gal. of water	4	1	8	1	8	8	8	1	8
Relative cost of chemicals*	136	121	148	102	104	118	150	107	111

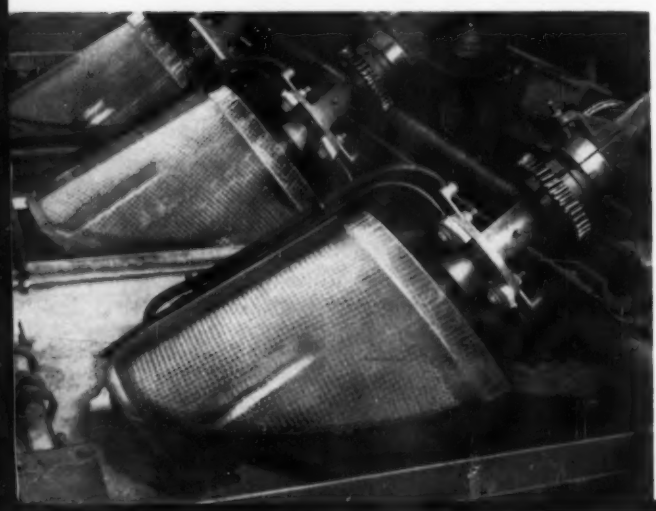
*The cost index is based on the lowest-cost formulation (spray zinc) as 100. The base value of 100 corresponds to a cost of $4.00 to $8.00 per 100 lb. of the cleaner formulation, depending on quantity and local purchasing conditions.

Phosphates such as trisodium phosphate, tetrasodium pyrophosphate, and sodium tripolyphosphate serve as water softeners. They impart alkalinity, rinsability, and some buffering action, and are fair emulsifiers. Tetrasodium pyrophosphate and sodium tripolyphosphate have some sequestering properties.

Trisodium phosphate was the first phosphate to be widely used in cleaners. It is still the cheapest phosphate but its use is, nevertheless, declining. Trisodium phosphate contributes more alkali to a cleaner than the other phosphates but is less efficient as a water softener. Trisodium phosphate softens water by a reaction which produces insoluble precipitates less undesirable than the respective insoluble gelatinous soaps.

Tetrasodium pyrophosphate is a good water softener that sequesters magnesium and calcium to form a water-soluble complex. It is therefore more desirable than the precipitate-forming trisodium phosphate. Tetrasodium pyrophosphate is also a good emulsifier, detergent, dispersing and deflocculating agent. It is not only compatible with most builders but has synergistic action. Tetrasodium pyrophosphate, like all polyphosphates, will revert to the orthophosphate form. The rate of reversion depends on pH, temperature, time and concentration. This is not a serious disadvantage if small cleaner additions are made daily with the water additions to replace losses from drag-out and evaporation. Tetrasodium pyrophosphate is more stable at soak cleaner temperatures than trisodium phosphate.

Sodium tripolyphosphate (STPP) is the newest of the phosphates used in cleaners. It is the best water softener of the three phosphates. Household detergents frequently contain up to 40% STPP. It provides good cleaning action and works with surface active agents to produce a synergistic effect. Like tetrasodium pyrophosphate, sodium tripolyphosphate softens water by



Electrocleaning Stage of an Automatic Plating Machine. Brass parts loaded in lucite barrels move automatically from the cleaning solution to rinse and plating tanks. (Courtesy Spectranome Plating Co., New York)

	Magnesium		Zinc		
	Soak	Spray	Soak	Spray	Electrolytic
	20	20	—	15	15
	18	29	—	—	—
	—	—	—	35	34
	20	20	90	10	10
	—	—	—	—	—
	30	30	—	40	40
	5	—	5	—	—
	5	—	5	—	—
	2	—	—	—	—
	—	1	—	—	1
	200	170	180	170	180
	8	1	4	1	6
	150	107	194	100	104

sequestering. Sodium tripolyphosphate also contributes alkali to a cleaner, although less than the other two. Its main disadvantage is that it reverts to the ortho form at 180° F. somewhat more rapidly than tetrasodium pyrophosphate.

The formulator can determine the minimum concentration of phosphate theoretically required in a cleaner provided the sole function of the phosphate is to soften water. Of all the builders, the phosphates are the only ones for which the minimum required concentration can be calculated. The minimum concentration of phosphates required to soften 100 gal. of water is shown in the following tabulation.*

Water Hardness	Tetrasodium Pyrophosphate	Sodium Tripolyphosphate
At 77° F.		
75 ppm. $CaCO_3$	4.34 lb.	0.96 lb.
150	6.76	1.91
300	8.51	3.76
At 140° F.		
75 ppm. $CaCO_3$	2.08	0.58
150	3.50	1.25
300	5.17	2.16

For example, if the water hardness were 300 ppm. $CaCO_3$, either 5.17 lb. of tetrasodium pyrophosphate or 2.16 lb. of sodium tripolyphosphate would be required to soften 100 gal. at 140° F. The formulated cleaner solution, at a concentration of 8 oz. per gal., would have to contain a minimum of 10.34% tetrasodium pyrophosphate or 4.32% sodium tripolyphosphate to soften the water. It is well to provide an excess of these phosphates to take care of water additions and to allow the phosphates to exercise other beneficial effects such as detergency.

*Quantities are actual, not theoretical. Trisodium phosphate is not recommended for this application because it softens water only by precipitation. The two phosphates above act by a combination of precipitation and sequestration.

Silicates account for the bulk of most heavy-duty alkaline soak cleaners. Sodium orthosilicate, sodium metasilicate and sodium sesquisilicate are excellent emulsifiers, good buffers at pH values above 9, hold soil or dirt in suspension, and provide active alkalinity.

Sodium silicates can be obtained either in a viscous liquid or crystalline form. Crystalline silicates, which are discussed in this article, are preferred because of their purity and ease of handling. The sodium silicates used in cleaners differ chemically only by their $Na_2O:SiO_2$ ratio. Selection of the minimum concentration or quantity seems to depend on the other cleaner constituents and the type of soil to be removed.

Sodium orthosilicate is produced in large quantities in the anhydrous form and may offer advantages over the pentahydrated metasilicate. Sodium orthosilicate is highly alkaline and therefore a very harsh cleaner. It is a more expensive builder than anhydrous sodium metasilicate. Even though the alkalinity, as indicated by the $Na_2O:SiO_2$ ratio, may be the same as that of the ortho it is more economical to add the required amounts of meta and caustic soda to obtain this ratio since both meta and caustic soda are cheaper. However, some investigators have questioned that the cleaning action is the same. Both anhydrous ortho and meta are good builders because they allow the use of other important builders. The space occupied by the water of crystallization in hydrated builders, such as pentahydrated meta, is available for other ingredients when anhydrous builders are used.

Sodium metasilicate is the silicate most commonly used in metal cleaners. It is approximately the same price or slightly cheaper than the other silicates and is more versatile because the $Na_2O:SiO_2$ ratio can be easily adjusted over a wider range than for the others simply by adding caustic. This $Na_2O:SiO_2$ ratio is an important factor in cleaner efficiency and generally should be higher for saponifiable soils than for most other soils. There is no all-purpose $Na_2O:SiO_2$ ratio. Thus there is no all-purpose metal cleaner.

Sodium sesquisilicate is rarely used in cleaners. It is not produced in the large quantities that meta and ortho are, and therefore is higher in

cost. Most commercial-grade sesqui contains a considerable amount of meta.

Hydroxide – Sodium hydroxide or caustic soda is cheap and often the principal builder for supplying the necessary alkalinity. In addition, it increases electrical conductivity of the solution and improves saponification. However, its detergent ability is very poor for the nonsaponifiable soils and it has the poorest rinsing properties of all the common builders. It is also hygroscopic.

Surface Active Agents

Soap and detergents lower surface and interfacial tensions. The soap used in alkaline cleaners must be cheap if the cleaner is to be competitively priced. For this reason, sodium resinate, a byproduct of the Kraft papermaking process, is extensively used instead of the common animal fat soaps such as sodium laurate, palmitate or stearate. Several grades of resinate are commercially available.

The higher and lower grades of sodium resinate are usually avoided, and middle grades are used most. Higher grades are more costly, due to their refining, but produce only slightly better cleaning than the middle grades. The low grades contain a fairly high content of unsaponified fatty acids, which form insoluble calcium, magnesium and iron soaps with hard water. They should be used with a water-softening agent. Small amounts of resin soaps do not lower the surface and interfacial tensions as much as synthetic wetting agents but they are much cheaper. Resinates also emulsify certain soils more easily than the syndets (synthetic detergents), thereby justifying their use in alkaline cleaners. Most soak-type cleaners contain both resinates and syndets.

Synthetic wetting agents are extensively used in soak cleaners because they are freer-rinsing than soaps, aid soil dispersion, and prevent resoiling. They are effective in softening hard water and in lowering surface and interfacial tensions. In addition, synthetic wetting agents are less susceptible than soaps to contamination by acid residues. Two types are seldom, if ever, used; these are the cationic and mixed cationic-anionics. Both are expensive and the cationics are easily precipitated in the presence of soap. The remaining types, anionics and nonionics, are commonly used. The usual concentration range is 0.01 to 1% active.

The anionics, though still expensive, are generally the cheapest syndets because they are made in larger quantities. The anionics are available as white flakes and when in solution produce abundant suds. Alkylaryl sodium sulphonate is the most extensively used anionic. It is usually purchased as 40% active. It foams profusely but has good detergency.

The nonionics at room temperature are usually viscous, light-colored liquids, 100% active. They usually produce less suds than the anionics. When 1 or 2% of this liquid is mixed with the dry ingredients of alkaline cleaners, it dedusts by wetting down the fines and virtually eliminates stratification during shipment. The nonionics most commonly used are sulphonated esters and ethers, and the polyoxyethylene type. The latter is a combination of ethylene oxide condensed on a base such as polyoxypropylene. Lower percentages of ethylene oxide increase solubility in oil (hydrophobic); higher percentages increase the solubility in water (hydrophilic).

By varying the amount of ethylene oxide, different properties are obtained. Foaming properties increase as the content is increased. Generally the ethylene oxide percentages should be as high as possible without producing excessive foaming of the cleaner, and the material should be in the liquid form at room temperature for dedusting and antistratification properties. Nonionics are usually stable in alkalis and most acids. However, the solubility in water decreases with increasing temperature, and in hot aqueous solutions the nonionics may come out of solution and float on top as a precipitate resembling chicken fat. The addition of an anionic will cause the nonionic to go back into solution and give a synergistic effect.

Typical Formulations

Several builders are used in a given cleaner in proportions that vary for each cleaning method and application. In addition to the effect of proportions on efficiency of cleaning, the characteristics of the builder must be considered in relation to the kind of soil being removed and to the metal being cleaned.

Typical formulations that employ some or all of the compounds discussed above are listed for each of the alkaline cleaning methods in Table IV. The formulations listed apply to average soils encountered in general plant processing. For milder conditions, the concentrations can be less than shown. For severe conditions, specialty cleaners may be required.

The solution should be stirred or agitated as the compound is added, with the addition being spread over a large area of the tank. These are safety measures against an explosion of hot caustic materials, which can result from the heat generated by a pile-up of the compound.

Aluminum Alters Density of Electrical Steel

*By ROBERT J. BENDURE**

The partial substitution of aluminum in many electrical steels has made necessary the re-evaluation of density formulas. A new formula, determined by graphical multiple correlation, is suggested as a replacement for the standard A.S.T.M. formula. (P10a, 2-60; ST, SGA-r)

TO DETERMINE ACCURATELY the magnetic properties and lamination factors of electrical steel sheets, the density of the steel must be known. Standard practice for many years has been to base such tests on density values assigned (for each of four silicon ranges) by the American Society for Testing Materials. However, in recent years aluminum frequently has been substituted for silicon in certain grades of electrical steel. Consequently, we decided to investigate the effect of aluminum, silicon and certain other elements on the density of electrical steel.

Eleven samples of thin bar, selected from different hot rolled silicon grades, were used for the experimental work. The analyses are shown in Table I. Naturally, for close measurements (by the weight-in-water/weight-in-air method) specimens must be clean and smooth. We sheared 2 × 3½-in. blanks from the hot rolled bar stock, and removed surface irregularities and scale by making a skin pass with a shaper. The samples were then degreased, lightly pickled in dilute hydrochloric acid and dried with an air blast. When the densities were determined, water temperatures were measured to 0.1° C., with corrections being made for the suspension system. Using this method, the maxi-

*Senior Chemist, Research Laboratories, Armco Steel Corp., Middletown, Ohio.

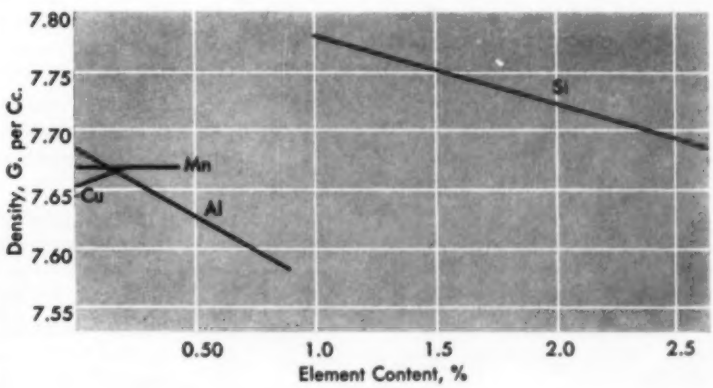


Fig. 1 – Final Approximations of Elements by the Graphical Multiple Correlation Method. Aluminum and silicon have the most marked effect on density

mum variation between duplicate determinations was found to be 0.0008 g. per cc.

After collecting all the needed density values, we made a study of the constituents using the graphical multiple correlation method. Since silicon, aluminum, copper and manganese are the only elements present in amounts large enough to have any appreciable effect on density, only these four were included in the study. The final approximations are shown in Fig. 1.

These curves cannot be used to determine density directly because the densities indicated on the ordinate have no real significance. The slopes of these, however, are significant and were found to be as follows:

Silicon	-0.05905 (b_1)
Aluminum	-0.11333 (b_2)
Copper	$+0.04444$ (b_3)
Manganese	0.000 (b_4)

The regression equation for this correlation would be represented by:

$$X = a + (b_1 \cdot \% \text{ Si}) + (b_2 \cdot \% \text{ Al}) + (b_3 \cdot \% \text{ Cu}) + (b_4 \cdot \% \text{ Mn}) \quad (1)$$

where b_1, b_2, b_3 and b_4 are the slopes. The value for "a" (which, here, is the density of pure iron) can be determined by substituting the known values in equation (1) so that:

$$\text{Determined density} = 11a^* - 0.0590\ \Sigma\text{Si} - 0.1133\ \Sigma\text{Al} + 0.0444\ \Sigma\text{Cu} + 0.000\Sigma\text{Mn} \quad (2)$$

Solving for "a" yields a value of 7.8508, and the regression equation now becomes:

$$\text{Density} = 7.8508 - 0.0590\ \text{Si} - 0.1133\ \text{Al} + 0.0444\ \text{Cu} \quad (3)$$

The density of pure iron has been established as 7.86, and "a" should not differ much from this. The fact that our value is slightly lower could be due to the combined effect of other elements present in trace amounts but which were not included in the correlation study.

The equation currently used by A.S.T.M. for density calculation is:

$$\text{Density} = 7.865 - (0.065 \times \% \text{ Si}) \quad (4)$$

In Table II we compare the accuracy of our equation (3) with that of the A.S.T.M. equation (4). With the exception of Sample No. 2, the calculated values by equation (3) are in excellent agreement with the determined values. When the actual densities are compared to the values by the A.S.T.M. equation, reasonably good agreement (except for sample No. 11) is obtained only for those samples with residual aluminum content. With added aluminum, agreement is poor.

We also tried our equation on two samples with high aluminum, and got the results shown in Table III. Differences between measured and calculated values are somewhat greater than with the previous samples. We believe this might indicate that the slope of the aluminum line is not constant. In other words, extrapolating so far beyond the limits of the original study introduces a slight error. To obtain more accurate density calculations when the aluminum content exceeds 1%, it would be necessary to

Table I – Analysis of Thin Bar

Sample	Silicon	Aluminum	Copper
1	1.38%	0.005%	0.18%
2	1.30	0.42	0.20
3	2.15	0.030	0.19
4	2.11	0.30	0.22
5	2.79	0.005	0.082
6	2.94	0.46	0.20
7	3.24	0.004	0.21
8	3.34	0.80	0.13
9	3.42	0.005	0.12
10	3.75	0.004	0.085
11	4.79	0.005	0.069

Table II – Calculated Vs. Determined Density

Sample	Actual Density	Armco Equation Calc.	Diff.	A.S.T.M. Equation Calc.	Diff.
1	7.776	7.777	−0.001	7.775	+0.001
2*	7.746	7.735	+0.011	7.780	−0.034
3*	7.725	7.729	−0.004	7.725	0.000
4*	7.702	7.702	0.000	7.728	−0.026
5	7.687	7.689	−0.002	7.684	+0.003
6*	7.636	7.634	+0.002	7.674	−0.038
7	7.663	7.668	−0.005	7.654	+0.009
8*	7.573	7.569	+0.004	7.648	−0.075
9	7.648	7.654	−0.006	7.643	+0.005
10	7.631	7.633	−0.002	7.621	+0.010
11	7.576	7.571	+0.005	7.554	+0.022

*Al present in added amounts.

Table III – Calculated Vs. Determined Density for High Aluminum Contents

Silicon	Aluminum	Copper	Determined Density	Calculated Density (Eq. 3)	Diff.
0.027%	2.74%	0.037%	7.57	7.55	+0.02
0.15	3.46	0.020	7.50	7.47	+0.03

*Each sum is the total of the values obtained in the 11 samples. Therefore "a" is multiplied by 11.

make a new study of samples with higher aluminum contents.

Summary

In view of the strong effect of aluminum on density, it would seem that aluminum, when present in added amounts, should be considered in density calculations.

Incidentally, our equation can be simplified somewhat. Copper in the range found in electrical steel would affect the density by less than 0.01, and manganese has no measureable effect.

The following simplified equation will give satisfactory accuracy in the 1 to 5% silicon and 0 to 1% aluminum ranges.

$$\text{Density (g. per cc.)} = 7.85 - 0.059\%\ \text{Si} - 0.113\%\ \text{Al} \qquad (5)$$

For practical purposes, the calculation can be further simplified without introducing an appreciable error, as follows:

$$\text{Density (g. per cc.)} = 7.85 - 0.059\ [\%\ \text{Si} + (\%\text{Al} \cdot 2)] \qquad (6)$$

Use of either equation should increase the accuracy of density determinations considerably.

Engineering Decisions Based on Irradiation Experiments

*By J. H. KITTEL and S. H. PAINE**

Since irradiation of experimental reactor parts is very costly in time and money and the existing facilities are exceedingly limited, fuel elements have been designed with only the scantiest of precise information about life expectancy – fortunately with no bad guesses made so far. (T11g, 2-67; U)

IRRADIATION STUDIES on reactor materials and components started in this country about 15 years ago. Although they were concerned primarily with structural materials, it soon became evident that *fuels* were generally much more susceptible to serious damage, since severe lattice disturbances occur near a fission event, and the new impurity atoms may be highly insoluble.

From these early beginnings the irradiation of fuel materials has assumed such importance that such studies are often the only tests applied to evaluate a proposed and untried fuel. The traditional tensile and mechanical tests by which the metallurgist is guided in other fields may often be omitted entirely.

Unfortunately, such indispensable irradiations are expensive, difficult and time-consuming. The studies require hazardous and costly materials, highly specialized fabrication facilities, expensive reactors and costly "hot labs" in which to examine the now highly radioactive parts. Furthermore, one must consider the cost in time represented by remote handling, and by specimens waiting to get into an overcrowded reactor or hot laboratory. Because all these factors often conspire with a rigid time schedule, only a small number of specimens can be usually irradiated for a given reactor program, even though the experimenters and designers are well aware of the desirability of safeguarding decisions by good statistics. Therefore the results from each specimen can assume rather great significance. For example, heat treatment of the fuel in an

*Metallurgy Div., Argonne National Laboratory, Lemont, Ill. This article is based on a paper presented to the American Nuclear Society in Los Angeles, June 2, 1958, entitled "Some Engineering Decisions Based on Fuel Damage Studies".

entire core may be based on the results from a single specimen which had apparently been given the optimum heat treatment before irradiation. (It should be mentioned, however, that this information would normally be supplemented by data from other specimens with supposedly non-optimum heat treatments.)

The following examples from experience at Argonne National Laboratory are given to illustrate the manner in which results from irradiation tests have determined the final specifications for fuel elements for reactors, or in some other way have influenced the reactor program itself.

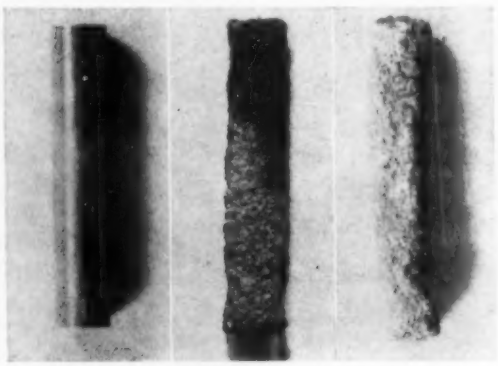
Daniels Pile

The high-temperature, gas-cooled reactor known as the "Daniels Pile" was proposed in 1944 and was under active study until 1947. Its design would even today, 12 years later, be regarded as highly advanced. The fuel was to be UO_2 in graphite, BeO, or beryllium metal, and the moderating material was to be BeO. Outlet gas temperature was to be 1400° F. The project was dropped because it appeared that adequate technology had not yet been developed to construct and operate the reactor. One of the difficulties which arose was the serious loss of thermal conductivity in the proposed fuels and moderator when they were subjected to irradiation. In the extreme case, irradiation of 98-2 BeO-UO_2 to only 300 megawatt-days per ton of fuel mixture decreased the thermal conductivity six-fold. Although never built, the Daniels Pile was probably the first reactor where fuel damage studies played an important part in a reactor's initial development – and eventual abandonment.

Fast Breeder Reactor

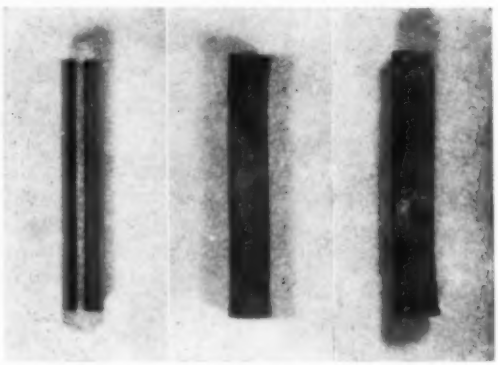
EBR-I (Experimental Breeder Reactor No. 1) is a fast reactor cooled with liquid metal built primarily to determine whether "breeding" is possible, and if so to give data for the eventual design of a fast breeder system. The reactor was put into operation at the National Reactor Testing Station in Idaho in 1951, and is successfully fulfilling its objective.

At the time when the fuel had to be selected, very little information on irradiation effects on uranium metal was available, and even less on uranium alloys. However, the indications were that the dimensional behavior of uranium under irradiation was similar to its behavior under thermal cycling. Because of this circumstance, and because adequate irradiation facilities were not available, thermal cycling tests were relied on almost entirely to evaluate the proposed fuel for the first core of EBR-I.



Zero *0.63%* *1.75%*

Fig. 1 – Effect of Irradiation on Bars of Uranium, Rolled at 300° C. (575° F.) and Quenched From the Beta Phase. Relative burn-ups are in atoms percent

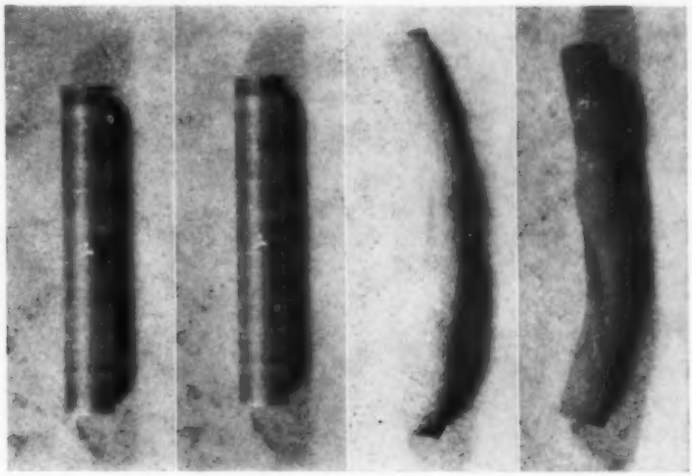


Zero *0.69%* *1.6%*

Fig. 2 – Comparative Irradiation on Cast U-Zr Alloy (1.6% Zr)

The material finally specified was uranium metal which had been rolled at 300° C. (575° F.) and quenched from the beta phase. Although this heat treatment did not stabilize the uranium entirely, it seemed to be the best procedure available. (As a matter of fact, beta-quenched material still is one of the most stable forms of unalloyed uranium known, and such uranium is still being specified for reactor fuel elements.)

During the first two years of operation with this core, we found that castings of uranium alloyed with approximately 2% zirconium performed much better under irradiation than beta-



A E C D

Fig. 3 – Effect of 0.060% Burn-Up on Uranium Alloyed With 1.5% Cb and 5% Zr, Heat Treated as in Table I

quenched uranium. Figures 1 and 2 illustrate this. Accordingly, in 1954, a second core was made from 98-2 U-Zr alloy and placed in the reactor. A third core, which is now in the reactor, required a rigid fuel assembly with metallurgically bonded cladding. The same 98-2 U-Zr alloy, co-extruded with Zircaloy-2* cladding, was used. The heat treatment that was selected to stabilize the fuel elements under irradiation was determined by irradiating small specimens after various promising heat treatments.

Boiling Water Reactor

The fuel material specified for the first loading of the experimental boiling water reactor (EBWR) was the corrosion resistant uranium alloy containing 1.5% Cb and 5% Zr. For maximum corrosion resistance, this alloy requires a metastable alpha structure which is obtained by quenching from the gamma phase, but by irradiating samples we learned that it was dimensionally unstable and elongated rapidly. Numerous heat treatments were then studied and the most stable structure was found to be an isothermal transformation at 650° C. (1200° F.).

This suggested a duplex heat treatment – first, an isothermal anneal for dimensional stabilization followed by a quench from the gamma phase to impart corrosion resistance. Unfortunately, when specimens with these duplex heat treatments were irradiated, they elongated as rapidly as though they had been given no stabilizing heat treatment at all. This is shown graphically in Fig. 3, and quantitatively in Table I where the growth rate is in micro-in. per in. for a burn-up of 1 part per million.

Table I – Dimensional Stability Vs. Heat Treatment

	Heat Treatment	Growth Rate*
A	As swaged	150
B	15 min. at 800° C. (1475° F.), furnace cooled	20
C	15 min. at 800° C. (1475° F.), 24 hr. at 650° C. (1200° F.), water quenched	6
D	10 min. at 800° C. (1475° F.), water quenched	290†
E	15 min. at 800° C. (1475° F.), 24 hr. at 650° C. (1200° F.); 10 min. at 800° C. (1475° F.), water quenched	280†

*Micro-in. per in. for a burn-up of 1 ppm.
†These treatments produce a corrosion resistant alloy.

Since time was limited, it was necessary to decide on the heat treatment for the core without additional information, and it was concluded that maximum dimensional stability was more important than maximum corrosion resistance. The entire fuel loading was therefore given merely the isothermal heat treatment noted in the third line of the above table. None of the plates have failed to date, after many months of service, so the plan to emphasize dimensional stability and to rely mainly on the cladding for corrosion resistance was apparently a good decision.

Borax-IV

Borax-IV is an experimental boiling water reactor at the National Reactor Testing Station in

*Nominal composition of Zircaloy-2 is 1.5% Sn, 0.15% Fe, 0.10% Cr and 0.05% Ni. Tin and iron strengthen the metal and reduce its corrosion resistance slightly.

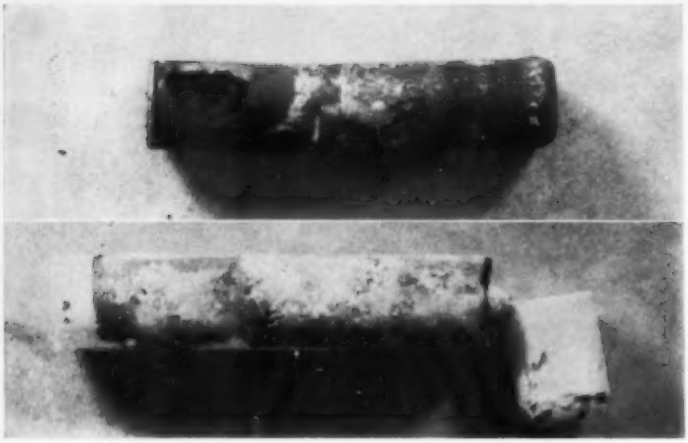


Fig. 4 – ThO_2-UO_2 Compacts After Irradiation and Partial Stripping of Cladding. Gas bonding, shown at top, allowed movement of fuel and burnout of cladding; lead bonding shown at bottom, kept fuel and cladding separate

Idaho and is operating with a ceramic fuel, ThO_2 with 6.36% UO_2 (much of which is the U^{235} isotope). We were interested in this type of fuel for two main reasons – first, the ThO_2-UO_2 pellets can be sintered in air, whereas UO_2 must be sintered in a protective atmosphere, and second, the thorium atoms in the fuel would provide highly useful information needed to design a thermal breeder based on the conversion of Th^{232} to U^{233}.

Before actually loading the reactor with this new and untried fuel, several irradiation tests were made to establish the performance of the ceramic pellets themselves and the preferred method of incorporating them into fuel elements. Pellets of ThO_2-UO_2 proved to be highly stable dimensionally under irradiation; cylindrical specimens ¼ in. diameter and ¾ in. long irradiated to burn-ups as high as 0.75% of the metal atoms, or 5600 megawatt-days per ton of oxide, lengthened less than 0.0002 in.

Small experimental assemblies were then clad and encapsuled with NaK and irradiated to determine the suitability of the 99-1 Al-Ni alloy cladding. Two methods of bonding the pellets to the cladding were investigated: In one arrangement, the annulus between the ceramic pellets and the aluminum alloy cladding was filled with a mixture of helium and argon. In the other, lead was used as a bond. Each NaK capsule contained one gas-bonded and one lead-bonded assembly.

The experiments showed that lead bonding would permit higher average heat fluxes to pass through the aluminum alloy cladding than would gas bonding. For example, in one test ending with 0.64% atomic burn-up at 425,000 Btu. per hr. per sq.ft., the cladding on the gas-bonded assembly cracked longitudinally, whereas the lead-bonded assembly was undamaged. Figure 4 shows these two specimens with the cladding partially removed. It can be noted that a fragment of fuel in the gas-bonded specimen has moved sufficiently to contact the cladding, and this apparently resulted in a local failure from overheating. In the lead-bonded assembly, the fuel fragments have remained in place, with none moving sufficiently to come into contact with the aluminum.

Such information, obtained from these irradiation studies, was in large part responsible for the decision to use ThO_2-UO_2 fuel in Borax-IV, and to bond the ceramic pellets to the cladding with lead. Furthermore, its excellent performance has led to its use in other reactors to be built in this country.

Conclusion

The foregoing account illustrates how, at one laboratory, important engineering decisions pertaining to almost every reactor it has designed or built have been based on fuel damage studies. This experience is by no means unique to Argonne National Laboratory. Probably every major reactor development or reactor construction group in this country has relied equally as heavily on fuel irradiation studies to at least guide its fuel element designs. For example, in *Metal Progress* for April 1959, B. Lustman describes the extended work the Westinghouse organization did on the enriched uranium oxide pellets used in the Shippingport reactor. With increasing emphasis being placed on high burn-up at high temperatures for power reactor fuels, it can be predicted that fuel damage studies will take on ever-increasing importance.

Metals Documentation

—a Fast New Problem-Solving Service

By MARJORIE R. HYSLOP*

Literature searching by machine is fast, thorough and prompt. The new ASM Metals Documentation Service will provide, at two-week intervals, abstracts of all current publications pertaining exactly to the subscriber's problems. Ultimately, bibliographic searches of all metallurgical documents published in preceding years will be provided overnight. (A14e)

THE CHIEF METALLURGIST of a prominent American steel company recently described an experience which is typical of the frustrating situation confronting today's engineers and researchers. This steel company owns ore mines in a remote section of Africa. A 40-mile railroad transports the ore to the coast for shipping to the United States. Everything at the mine was running smoothly until one day suddenly, without warning and with no apparent reason, an epidemic of rail fractures halted operations. The ore could not get to the coast, ships were delayed, and emergency measures were necessary. So, without further ado, the mine manager cabled the home office in the United States. What should he do, he asked, to prevent any further rail failures. Were his loads too heavy? Were the railroad ties set too far apart? Were there too many flat wheels? Was there some metallurgical defect or shortcoming in the steel? The failures, he said, included fissures, split heads and broken rail bases.

The chief metallurgist did not have the answer and did not know where to get it in a hurry. He knew that rail failures were epidemic a generation ago and that somewhere in a technical paper published in a technical journal he would find a description of a similar problem, its cause and cure. His only recourse was an expensive and – what's worse – time-consuming search of the literature. He did find the answer eventually†, but if, said the man, he had known where to get it overnight, it would have saved his company actually thousands of dollars.

Then there is a somewhat different angle to this same problem. We all know how urgent is the problem of developing metals that will be hardy enough to withstand the rigors of space travel and that will hold together at the tremendously high temperatures engendered when a rocket or a missile re-enters the atmosphere at thermospheric speed. Yet there is a paucity of information on the strength of metal at high temperature because the standardized creep and stress-rupture tests are expensive and take a *very* long time. For this reason many laboratories have been trying to find some relationships between the less expensive and shorter tests, such as hot hardness or hot tensile, and creep or stress-rupture properties. There are perhaps good theoretical reasons for suspecting that no accurate relationship exists. Nevertheless, many investigators are convinced that there is a usable correlation. If such a relationship could be found, the improvement of heat resisting metals would be speeded up and at the same time a considerable savings would be realized by substituting the simpler tests.

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*Editor, ASM *Review of Metal Literature;* Managing Editor, *Metal Progress,* Cleveland.

†"Railway Track Materials", Steel Products Manual, American Iron and Steel Institute, April 1955.

Now we know of at least one research metallurgist who is working pretty steadily on this problem. He knows it is being tackled in many other laboratories throughout the world. Reports of what these other laboratories are doing appear almost every day in hundreds of journals, magazines and other publications ranging from, shall we say, *Metal Progress* to *Ke-Hsueh-Tung-Pao* (in case you don't know, an important Chinese scientific journal). His particular problem may be treated in one or more of these journals at almost any time. The importance to this particular metallurgist of knowing about these publications is obvious. The impossibility of his knowing about them personally, without outside help to winnow the massive literature, is also obvious. Furthermore, he wants to know about them *immediately* after their publication, not six months or a year later.

Literature Searching by Machine

In an effort to solve these two types of problems – representative only of many, many others – the American Society for Metals is embarking on a new venture called the Metals Documentation Service. This service, to be inaugurated early in 1960, is the culmination of four years of research and pilot-plant experience in the indexing and searching of metallurgical literature *by machine*. These last two words – by machine – are the key that unlocks the door to a literature searching service which is not only thorough but is also fast, up-to-date and tailored to the exact needs of the individual.

A "fast" service means that the machine will be able to search 100,000 indexed documents per hour and print out titles and sources of those that are pertinent to the question which has been asked of it. Compare this figure of 100,000 per hour to the 12,000 metallurgical documents that constitute an entire year's abstracts published in the *Review of Metal Literature!*

An "up-to-date" service means that journals and other publications will be indexed on magnetic tape ready for searching within one or two weeks after publication for domestic journals and within about a month for foreign.

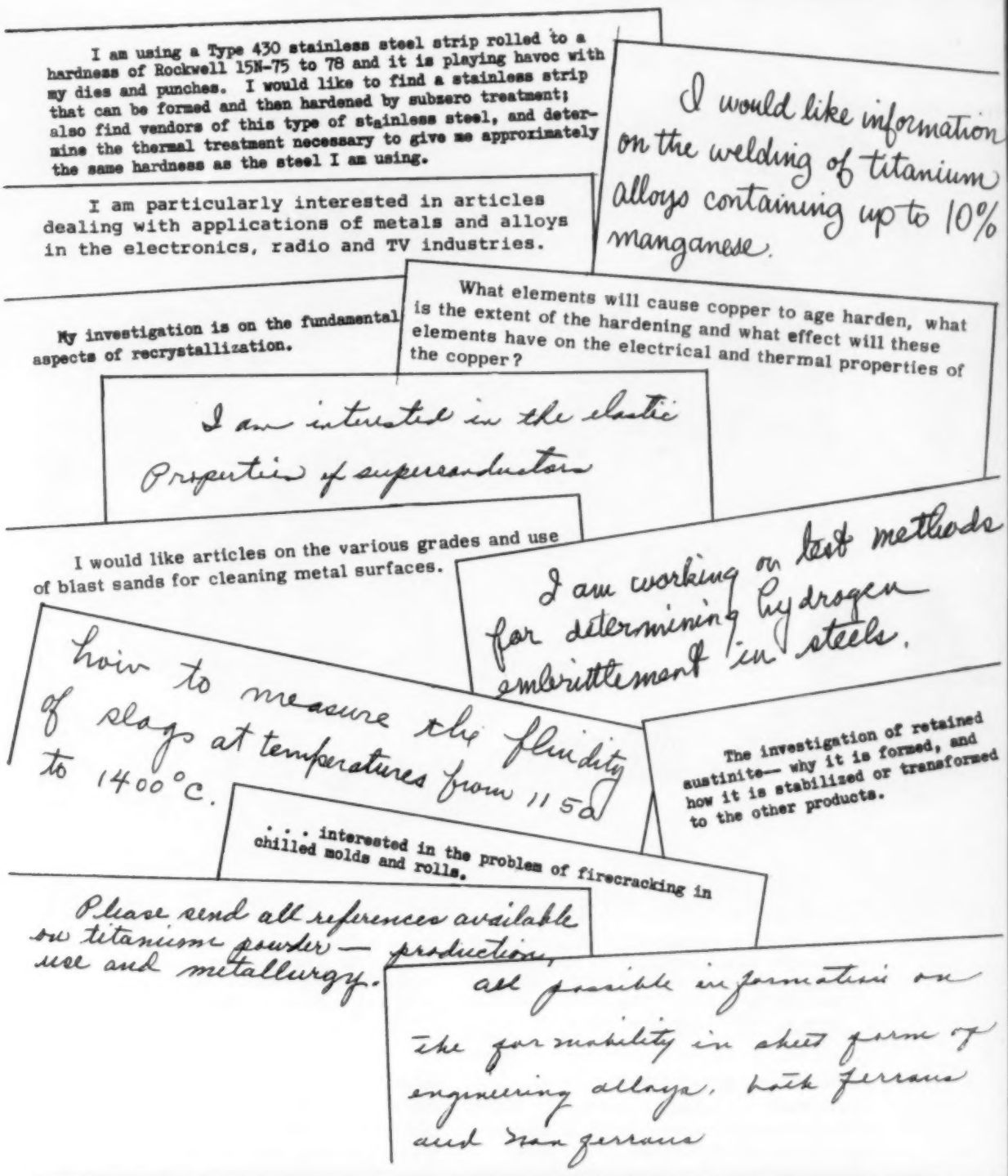
A "tailor-made" service means that the subscriber will describe his problem specifically and be reasonably sure that the machine will automatically provide any necessary synonyms, semantic and syntactic relationships so that the abstracts delivered to him will have a definite and significant bearing on his question. (These relationships of ideas automatically follow from the method of indexing and the operation of the electronic marvel called the searching machine.) How complex some of these questions can become will be shown a little later. But first let us examine the purpose, operation, scope and products of the new service.

Purpose will be to provide a selecting, abstracting and searching service covering the world's published metallurgical literature. As indicated above, emphasis will be placed on promptness, comprehensiveness, thoroughness of indexing and efficiency of retrieval. No attempt will be made to *evaluate* information critically or to provide specific items of information not available in the published literature – *that* would be the function of the recipient, his staff or consultants.

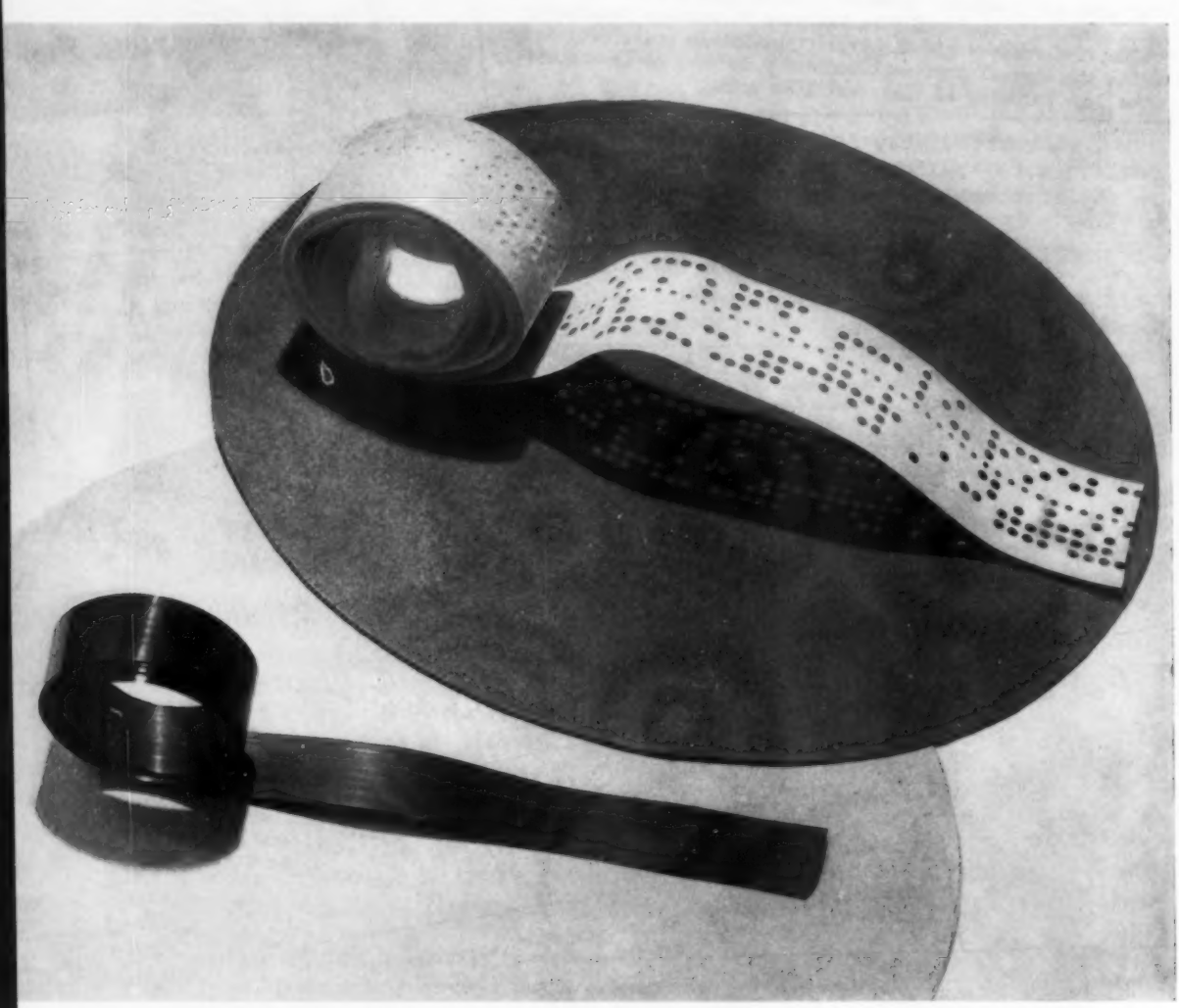
Operation – The service is built upon three foundation stones – first, the abstracting service known as the *Review of Metal Literature;* second, a highly refined and very effective method of subject analysis developed by James W. Perry and Allen Kent of the Center for Documentation and Communication Research at Western Reserve University, where the A.S.M.-sponsored research was conducted; and third, a brand new "information searching selector", the GE 250, being built by General Electric Co., according to designs also developed at the Western Reserve University Documentation Center (see photo, p. 126). All of the 12,000 articles, books and other publications abstracted for the *Review of Metal Literature* will be simultaneously indexed and encoded on magnetic tape, ready for machine searching at a moment's notice.

Scope – For the purposes of the *Review of Metal Literature,* "Metallurgy" is defined as follows: "Metallurgy means the arts and sciences underlying the production of any metal from its ore or concentrate; its refining, alloying and manufacture into mill shapes including foundry and forge; machining, forming or shaping operations where quality of metal or tool is critical; heat treatment and welding. It includes research into and production of conventional metals and alloys and new variations to meet special services. It includes data on properties, and on performance in any environment. It includes equipment and methods for inspection and research. It includes metallurgical education and history."

The American Society for Metals has recognized from the start of the research project on mechanized searching that this definition is rather restricted and that most metallurgists have correlated problems in such adjoining fields as chemistry, physics, business and economics, and



other materials besides metals. Therefore, an early stipulation was that the system devised for indexing and searching *metallurgical* literature be capable of extension into wider fields of knowledge. Plans are now under way for extending the metallurgical coverage into some "fringe" areas around the central core as defined above, together with an enlargement into some of the neighboring and closely related fields — solid-state physics, for example. It is entirely



Two Types of Encoded Tape for the Machine Searching Library. Below is the magnetic tape which will be used in the GE 250 information searching selector, and at top is a corresponding piece of punched paper tape used in the experimental machine designed and built at Western Reserve University and used as prototype for the GE 250. The paper tapes containing encoded portions of the literature of the past five years are now in process of conversion to magnetic tape

possible that the ASM Metals Documentation Service eventually will include something like 40,000 documents per year rather than the 12,000 represented in the A.S.M. definition of metallurgy.

While the service is limited to published metallurgical literature, the interpretation of "published" is quite broad. It leans of course most heavily upon the world's technical and scientific periodical literature and books. Miscellaneous material includes a large segment of the unclassified government reports (U.S. and foreign), monographs from private sources, and commercial publications (house organs) which contain valuable technical information. Even mimeographed papers are included just as long as they are fairly readily available either on request or by purchase. The searching service does not now extended into patents and dissertations, but these can be added as the scope is broadened.

Products – The most immediate product will be what may be called a "current awareness" service. This is designed to meet the needs of the research worker or engineer who wants to be kept *currently* and *promptly* informed of *all* in-

formation being published relating to the particular problem he is studying at the moment. This is the kind of requirement posed by the research metallurgist cited above who is trying to develop simple, short-time tests for resistance to high temperatures. Such a man would subscribe to the service for a year. At two-week intervals he will receive a collection of abstracts pertaining specifically to his problem and taken from the literature published during the preceding two weeks. He will also have the privilege of ordering from the ⊜ photocopy service copies of documents which are not readily available to him.

(Incidentally it should be mentioned that the ⊜ *Review of Metal Literature* will be continued in its present form — a monthly publication containing indicative abstracts or annotations, sent free to A.S.M. members on request, and to others at a nominal subscription fee. The information fed into the machine system, however — the so called telegraphic abstract — is much more detailed than that contained in the printed abstracts. In other words the documents are analyzed in much greater depth for machine searching than for the printed abstracts.)

A second product available for a fee will be bibliographic or retrospective searches of previously published literature going back over a considerable time span. An illustration would be the search needed by the steel company's metallurgist facing the rail fracture problem. Overnight provision of such bibliographies is the ultimate aim of the Metals Documentation Service. It would be unrealistic, in fact impossible, to offer such rapid-fire delivery at the beginning, simply because the machine library — the magnetic tapes containing the encoded indexing — has not yet been built up to a comprehensive coverage. However, there does exist a backlog of encoded abstracts dating back to 1955 when the ⊜ research project was started, but the coverage is spotty and scant — only that necessary to get a "yes" or "no" answer to the main question: "Is mechanical searching feasible?"

This does not mean that bibliographic searches will not be available from the Metals Documentation Service. Present plans are to offer searches dating back at least five years, wherein the work that the machine can do will be supplemented by conventional library tools and indexes. Such library work simply cannot be done overnight. It requires much time and skill on the part of a trained reference librarian or literature researcher to ferret out the appropriate index entries in a wide variety of reference sources and then to trail the entries back to the related abstract or title and finally to locate the document itself. But when, in the not too distant future, a complete machine library is available covering a span of ten years — or even five years — it will be no trick at all to program the machine for the question, feed in the tapes, and in an hour or less produce a printed bibliography of all the recent (and most important) literature.

A third product will be encoded tapes of a year's literature for sale to those who want to install a searching machine in their own plants. The advantage to them would be the ability to search any combination or series of desired questions at any time and also to prepare tapes of their own containing information that is either confidential or on subjects not included in the A.S.M. service.

Still a fourth product may be called "generic searches". As contrasted to the custom-tailored search ordered to the individual's specifications, the generic searches will be on subjects of broad general interest which will have a fairly wide appeal — for example, vacuum melting, or fatigue testing, or oxygen steelmaking. The subscriber to a generic search will generally receive a larger slice of literature than he actually wants and will have to do some weeding on his own, but because it is more or less "mass produced" the cost will be considerably less than the specially ordered individual search.

The Test Program

An important phase of the five-year research project supported by the American Society for Metals which has culminated in the forthcoming Metals Documentation Service described above was a continuing and carefully worked out test program — actually an operating pilot plant! During the past year, the ⊜ research took the form of a reasonable facsimile of a current awareness searching service for ten customers. The ten questions were selected to represent important current problems to each of ten cooperating firms or organizations; they represented a good cross section of the subject matter and a range of complexity; the "customers" consisted of a diverse group of collaborators including research laboratories, metallurgical departments of large companies, company libraries, government departments, and a university. For example, two questions were submitted by the research and engineering office of the Department of Defense.

One concerned the notch sensitivity of high-strength steels (230,000 psi. yield strength and

above). These steels included hot die steels, low-alloy steels such as A.I.S.I. 4340, martensitic stainless steels, and precipitation hardening stainless steels. The metal was to be used in lightweight vessels subjected to high pressure, as in solid-propellent rocket casings. Metallurgical notches such as are imposed by welding, scratches and mechanical notches of various sorts cause premature failure in such vessels when the strength of the metal is high and its ductility low. It was therefore important to the Government to know what promising lines of research are being undertaken to overcome notch sensitivity of high-strength steel and what avenues of research deserve more energetic support.

The second question had to do with the light metal, beryllium, which has a number of most attractive properties in connection with its potential use in advanced weapons systems. Unfortunately, commercial beryllium is extremely brittle, and a search was therefore undertaken to determine what approaches have been suggested for overcoming this problem and what avenues now offer greatest promise of successfully overcoming this handicap.

From the research laboratory of a manufacturing company came a request for a comparison of physical characteristics of metal parts made by casting, by forging, and by powder metallurgy techniques. Although the company was not in the powder metallurgy business, they were studying a process which promised to give uniquely fine metal powders, and the properties of parts made from these powders, they hoped, would be superior to those of parts made from conventional powders. While they could run comparisons between powders, it would be more difficult to compare similar castings or forgings. They felt that the improvement in properties by using their materials might be enough to swing the production method from one of casting to one of powder metallurgy. In that state of development, some comparative information was vitally important.

Another manufacturing company asked for a continuing search on the development and applications of the refractory metals columbium, molybdenum, tantalum and tungsten for such applications as rocket motors, gas turbines and airfoil shapes subjected to aerodynamic heating. The combination of properties being sought included high-temperature strength, inertness to oxidizing and air environments, ductility and fabricability. At the present time, it is not clear which of the refractory metals or their alloys will be most useful for each of the applications cited, and a number of scientific and engineering development programs are now in progress throughout the country aimed at establishing the merits and potentialities of each of these metals. In planning and guiding their own studies, it would be most helpful, they said, to be aware of all progress being made in as many places as possible.

Samples of other current problems submitted during the test program are given on p. 125.

Conclusion

Anyone who has ever done any literature research will recognize the complexity of some of these questions. For example, in the question on notch sensitivity, "high-strength steel" cannot be searched as such in an index, and recover all of the types listed by the questioner, both low-alloy and high-alloy. Also "notch sensitivity" must be further defined in terms of index entries.

It would be impossible in the space alloted here to explain the internal mechanics of the machine's "intellectual" operations; it does, however, provide two important functions that partially account for its thoroughness and for its speed. One is a built-in "code dictionary" which provides synonymous and generic concepts as required, plus some very useful syntax so that the human intellectual labor required to analyze a question is substantially reinforced. It is doubtful that the human factor can ever be eliminated completely, and skilled operators are being trained to make sure not only that the appropriate document analysis is fed into the machine library but also that the questions are properly interpreted in programing the machine for search.

The second improvement over manual methods (and one of the factors entering into the fast operation of a machine system) is that all of the indexing entries required for a document, whether 10 or 100, can be searched simultaneously. This is something that is certainly beyond the ability of the human brain.

Inquiries about the new service will be welcome. It will start functioning in January 1960, and it is not too soon to send in the details of your particular literature searching problem. Whether it is similar to any of those described in this article or whether it is something entirely different, chances are that the new tailor-made service can give you some help. Send your question or problem to the Metals Documentation Service, American Society for Metals, Metals Park, Novelty, Ohio.

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Short Runs

Forming Complex Parts From Wire and Strip

*By H. W. WHITMAN**

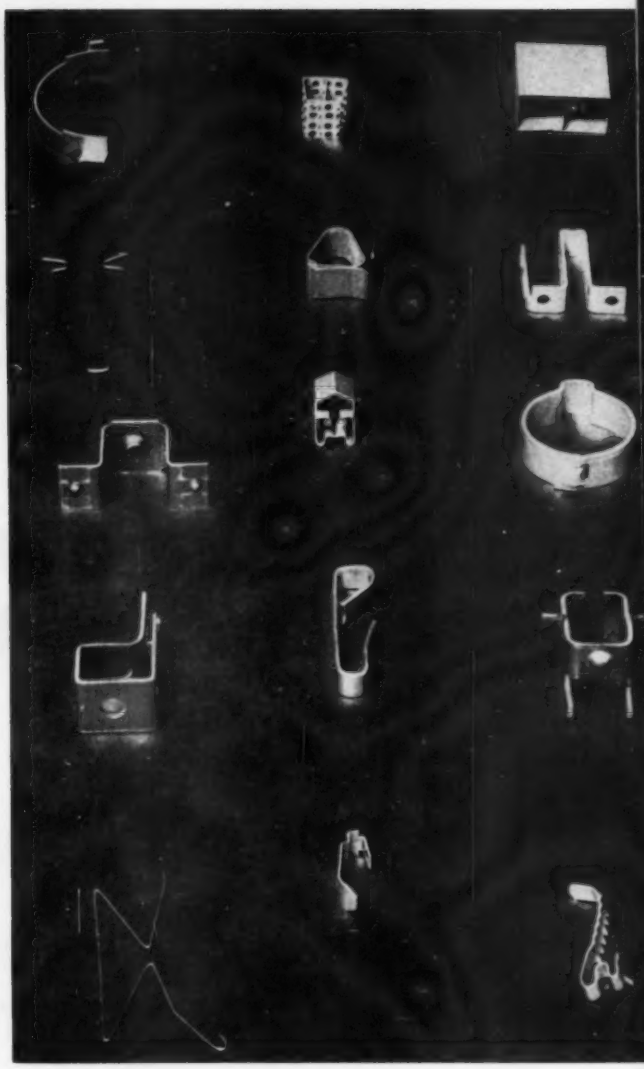


Fig. 1 — These Are Some Parts That Are Made by the Vertical Four-Slide. Note the wide variety of shapes and sizes that are possible

VERTICAL FOUR-SLIDE MACHINES for high-speed forming of wire and strip parts have only been available in the last two years. One example, the Torrington Verti-Slide was first introduced in 1957. The vertical form has since been broadly accepted by the metalworking industry. Vertical designs of any make have good visibility and accessibility to all parts of the machine, particularly the forming area, and take up little floor space. Setup time and tooling cost are fairly low since most operations can be conveniently performed by the setup man as he stands in front of the machine. Adjustment of the feed stroke, cams, presses and cutoff on the vertical machine are made at the same position.

Floor space required by the illustrated ma-

*Vice-President and General Manager, Machine Division, Torrington Mfg. Co., Torrington, Conn.

chine, for example, is only about half that needed for the more familiar horizontal machine. Though it is equal in length, it has but about half the width of most horizontal designs. Also, the machine needs no large opening in the bed for the completed parts since they are ejected from the front of the machine. Conveying and handling for secondary operations can be easily mechanized.

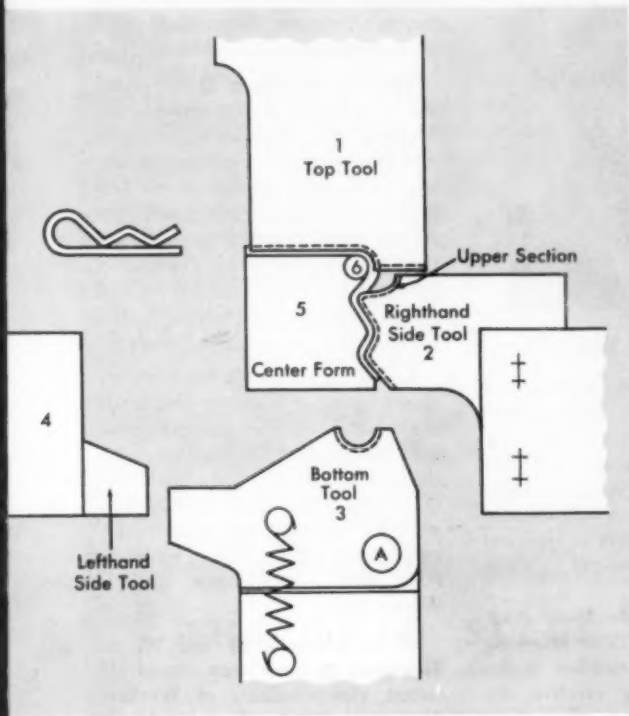
A major characteristic in which the vertical form differs substantially from horizontal machines is the design of center forms. They have a greatly reduced overhang, making them more rigid in construction. If advantageous in producing a particular part, the center form may be retracted at the end of a forming cycle to eject the part; this eliminates the need for any knockout pin.

Low Cost and Versatility

Each of the strip and wire parts shown in Fig. 1 can be economically produced on vertical four-slide machines. Though most must be formed to close tolerances, each can be completed automatically on the machine in one cycle of press and slide action, with no additional operations.

As an example of the job this equipment can do, a midwestern manufacturer of industrial heating equipment is producing a small phosphor-bronze part at a forming rate of 12,000 pieces per hour – four times the rate of conventional equipment. Both the original cost of the forming equipment (one vertical four-slide replacing five presses) and unit cost of the piece have been reduced more than 50%. To take full advantage of the production capacity of the machine and the ease with which it can be set up for forming other parts, tool engineers with this company plan to assign more than 20 additional precision strip and wire parts to the same machine.

Fig. 2 – How the Clip in the Upper Left-Hand Corner Is Made. A full description of each step can be found in the text



How Parts Are Formed

As an example of what can be done, the clip depicted in Fig. 2 is being produced completely in the tooling area of a vertical four-slide machine by four slide tools and a retractable double center form. Although the part is being shaped in only one plane, two waves in one leg must exert tension against the straight section. This is a familiar and often difficult problem in tool design. It was solved here by pivoting and deflecting the bottom tool to pinch the wire about the arbor of the center form. The forming sequence is as follows:

1. *Top tool* (1) moves down to curve the wire partially over the top right corner of the center form.
2. *Right-hand side tool* (2) moves in to form the waves in the wire against the right side of the center form.
3. *Center form* (5) retracts and allows the wire to rest on the *arbor* (6) extending outward from the center form.
4. *Right-hand side tool* moves in again and its upper section forms the wire against the underside of the arbor.
5. *Bottom tool* (3) moves up and *left-hand side tool* (4) moves in. As the sloping surface facing up on the left-hand side tool meets and slides along the sloping surface facing down at the left of the bottom tool, the bottom tool is pivoted clockwise about point A. The semicircular forming surface of the bottom tool then pinches the wire over the arbor against the straight section.
6. *Arbor* is fully retracted and the completed part falls off.

The amount of pinching action by the bottom tool and the shape of the arbor control the degree of tension of the wavy leg against the straight leg of the part.

Personal Mention

W. H. Boyd

W. H. Boyd has acquired the controlling interest of Gas Atmospheres, Inc., in Cleveland. At the same time, he has been elected president and treasurer of the company. Mr. Boyd has been with Gas Atmospheres since 1947, serving in various engineering and service capacities until becoming sales manager in 1950. He was appointed general manager of the operation in 1957.

He received his education in mechanical engineering at Pennsylvania State University, and worked for the Valley Brick Co. and Aluminum Co. of America before entering the Army Air Force during World War II for a three-year tour of duty as an operations officer stationed in England. Following the war, he was president of Flakota Crop Dusting Co. in Miami, Fla., until joining Gas Atmospheres.

In addition to A.S.M. membership, he is a member of the American Oil Chemists Society. One of his interests is flying and he has a commercial pilot license.

Robert G. Griffith has been appointed superintendent of the seamless tube mills of the Youngstown Sheet and Tube Co. Campbell works.

James J. Downs, after receiving a degree in metallurgical engineering from the University of Wisconsin, accepted a position as research metallurgist with the American Steel Foundries manufacturing research laboratory in East Chicago, Ind.

Donald E. Thomas has been appointed manager of metallurgy in the newly formed astronuclear laboratory of the Westinghouse Atomic Power Div., Pittsburgh. He was formerly manager, naval reactor metallurgy, at the Westinghouse Bettis Laboratory.

Thomas W. Wright has been named assistant manager of the New York district sales office of the Babcock & Wilcox Co. tubular products division. Mr. Wright, who has been a sales representative in the New York district since 1949, joined the company in 1946 and worked as a contact metallurgist at the tubular products division main plant in Beaver Falls, Pa.

Richard P. Simmons has been named manager of quality control by Latrobe Steel Co., Latrobe, Pa. Mr. Simmons was formerly manager of processing for Titanium Metals Corp. of America.

William J. Hilty

William J. Hilty has been promoted to advertising manager of *Metal Progress*. For the past year he had held the position of Cleveland-Pittsburgh regional manager (see *Metal Progress*, September 1958, p. 118) and prior to that was Cleveland district manager for three years.

Mr. Hilty joined the *Metal Progress* sales staff in 1955 following three years as staff member of the industrial advertising creative department of Fuller & Smith & Ross, Cleveland. Upon his release from the armed services in 1945, he enrolled in Fenn College and after receiving his bachelor's degree in 1948 joined Flxible Co. in Loudonville, Ohio, as advertising manager.

Richard B. Wagner has been assigned to the Lycoming Div. of the Avco Corp., Stratford, Conn., as manager of the materials process development department, missile systems. He was formerly with the research and advanced development division of Avco in Wilmington, Mass., as a section chief in the materials department.

Theodore A. Miller has been named resident salesman at Rockford, Ill., by the Latrobe Steel Co., Latrobe, Pa. Assigned to the Chicago office since 1957, Mr. Miller will continue to make this office his headquarters.

Bani R. Banerjee and **John G. McMullin** have been appointed section supervisors at Crucible Steel Co. of America's Central Research Laboratory. Dr. Banerjee, formerly senior project physicist with the Standard Oil Co. of Indiana, will head the applied physics section while Dr. McMullin, supervisor of metallurgy applied research at the General Electric Co. large steam turbine department prior to this, will be in charge of the constructional alloy steels research station.

James R. Robertson has joined the sales staff of Harper Electric Furnace Corp., Buffalo, N. Y. In his new post, he will direct the expansion of Harper activities in marketing gas-fired heat treating and nonferrous melting furnaces. For the past several years, Mr. Robertson held the position of president and general manager of Wayne Industrial Furnace Co.

Lowell C. Powell has been appointed product manager, heat treating equipment, for Salem-Brosius, Inc., Pittsburgh. He has been with the company since 1954 when it acquired the George J. Hagan Co., and prior to that time was district sales manager for the Hagan organizations with headquarters at Ft. Wayne, Ind.

N. A. Robinson and **W. A. Thompson** have been named assistant vice-presidents of Wyckoff Steel Co., Pittsburgh, with headquarters in Putnam, Conn., and Newark, N. J., respectively.

Personals . . .

Donald F. Ross has been promoted by the Carpenter Steel Co. of Reading, Pa., to Dayton-Cincinnati district manager. Ross, who joined the company in 1953, has served in Dayton as sales representative, assistant branch manager and branch manager.

J. J. Rozner has been elected president of the Aetna Ball and Roller Bearing Co., Chicago, by the Board of Directors of the parent organization, Parkersburg-Aetna Corp. He formerly served as vice-president of Aetna Ball and Roller Bearing.

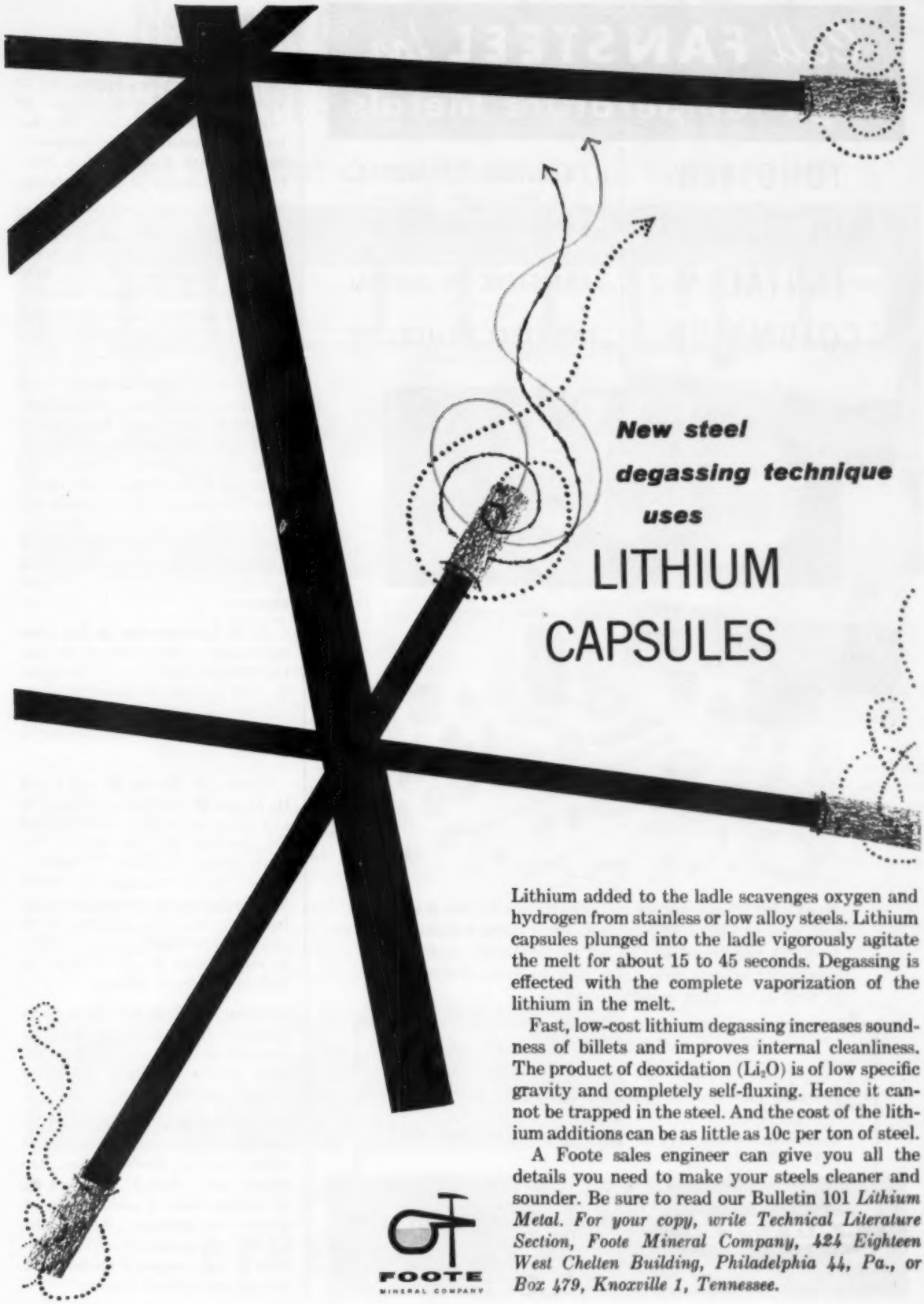
Raymond L. Smith, technical director of the research laboratories of the Franklin Institute in Pittsburgh, has accepted a position on the faculty of Michigan College of Mining and Technology, Houghton, Mich., as head of the department of metallurgical engineering. Dr. Smith was a member of the faculties of the University of Alaska and the University of Pennsylvania before joining the research staff of Franklin Institute in 1953.

Murray T. Stewart has joined the staff of the International Nickel Co. Research Laboratory at Bayonne, N. J., as a member of the special high-temperature alloys section, where he will devote his attention to the development of nickel alloys, particularly high-temperature alloys. Mr. Stewart, since 1952, was on the staff of Canadian Steel Improvement Ltd., Toronto, first as metallurgist and later as chief metallurgist.

Payne C. Barzler, Jr., has been promoted to product manager, tube and fittings, at Chase Brass & Copper Co., Waterbury, Conn. He was formerly district manager of the Chase branch at Houston, Tex.

Thomas W. Morrison has been appointed director of engineering and research for SKF Industries, Inc., Philadelphia. Mr. Morrison joined SKF in 1936 as a machinist in the research laboratory and last year was named assistant to the engineering and research vice-president.

Waldemar Naujoks has joined the Octigan Forging Div., of H & B American Machine Co., Chicago, as chief engineer.



New steel degassing technique uses

LITHIUM CAPSULES

Lithium added to the ladle scavenges oxygen and hydrogen from stainless or low alloy steels. Lithium capsules plunged into the ladle vigorously agitate the melt for about 15 to 45 seconds. Degassing is effected with the complete vaporization of the lithium in the melt.

Fast, low-cost lithium degassing increases soundness of billets and improves internal cleanliness. The product of deoxidation (Li_2O) is of low specific gravity and completely self-fluxing. Hence it cannot be trapped in the steel. And the cost of the lithium additions can be as little as 10c per ton of steel.

A Foote sales engineer can give you all the details you need to make your steels cleaner and sounder. Be sure to read our Bulletin 101 *Lithium Metal. For your copy, write Technical Literature Section, Foote Mineral Company, 424 Eighteen West Chelten Building, Philadelphia 44, Pa., or Box 479, Knoxville 1, Tennessee.*

FOOTE
MINERAL COMPANY

Personals . . .

J. G. Cametti, formerly manager of manufacturing engineering at Westinghouse Electric Corp.'s jet engine division in Kansas City, has been transferred to the company's Bettis Atomic Power Div. in Pittsburgh as manager of manufacturing engineering.

Chuan-Tseng Wei, who received his doctorate degree in metallurgical engineering recently from the University of Illinois, is now a research associate in the department of mining and metallurgical engineering of the University.

Bernard J. Alperin has been appointed manager of product engineering for the Everett Foundries of the General Electric Co. in Everett, Mass. Mr. Alperin, formerly assigned to G.E.'s Schenectady operations as development engineer for the applied research and development laboratory of the foundry department, has been supervisor of inspection in Everett for the past eight months.

E. K. Leavenworth has been appointed a vice-president of Climax Molybdenum Co. of Michigan. He will continue to make his headquarters at the company's Coldwater, Mich., plant where he serves as works manager.

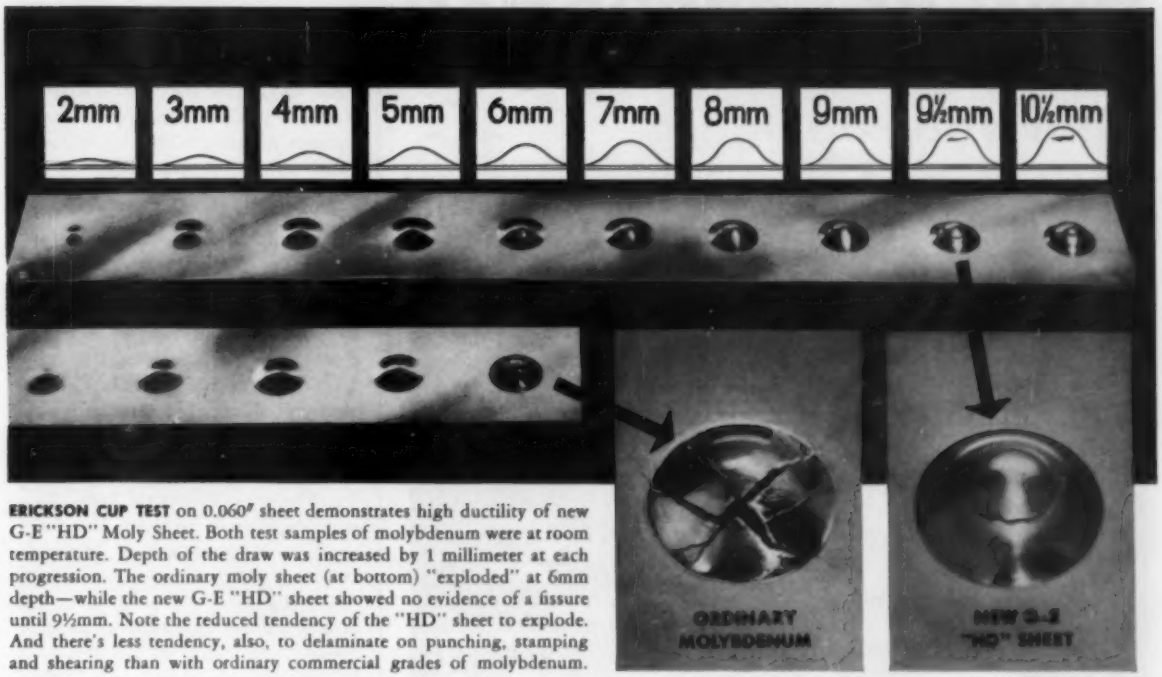
Charles H. Harton and **James H. Magee** have been assigned to new positions by the Carpenter Steel Co., Reading, Pa. Mr. Harton, formerly district manager in Buffalo, is now district manager in Cleveland, including the Toledo and Pittsburgh areas. Mr. Magee moves from the Cleveland territory, where he was assistant branch manager, to Buffalo as branch manager.

Walter C. Ibele was recently promoted from process engineer to general foreman in the seamless tube mills of the Campbell Works of Youngstown Sheet & Tube Co.

A. L. Poe is now district sales manager of the midwest district of Allied Research Products, Inc., Baltimore, Md., while **J. A. Cairns**, as vice-president of sales with headquarters in Baltimore, directs sales for the rest of the country not covered by the company's northeastern, central and midwest districts.

Now you can deep draw and bend molybdenum sheet at room temperature!

... with General Electric's new High-Ductility (HD) Molybdenum Sheet



ERICKSON CUP TEST on 0.060″ sheet demonstrates high ductility of new G-E "HD" Moly Sheet. Both test samples of molybdenum were at room temperature. Depth of the draw was increased by 1 millimeter at each progression. The ordinary moly sheet (at bottom) "exploded" at 6mm depth—while the new G-E "HD" sheet showed no evidence of a fissure until 9½mm. Note the reduced tendency of the "HD" sheet to explode. And there's less tendency, also, to delaminate on punching, stamping and shearing than with ordinary commercial grades of molybdenum.

DRAW IT! FORM IT! PUNCH IT!—all without preheating! General Electric's new "HD" Moly Sheet can take it—and you can do all these operations in thicknesses previously impossible . . . or requiring up to 1000°F preheating. Even in cases where small amounts of heat may be needed, it's always less than with ordinary molybdenum sheet.

TIME SAVER, MONEY SAVER! The improved ductility of General Electric's new "HD" Molybdenum Sheet is of particular significance in sheet thicknesses of 0.020″ to 0.125″—as used in electronic tubes and semiconductor diodes, rectifiers and similar products. It has a high melting point (2622°C, 4752°F), low vapor pressure, and excellent strength at elevated temperatures. So it will be of great value to any company using refractory metals.

PLAN ON G-E "HD" SHEET Available in commercial quantities, so there's no better time than right now to get all the facts about this new kind of molybdenum. Write: General Electric Co., Lamp Metals and Components Dept. MP-11, 21800 Tungsten Road, Cleveland 17, Ohio.

BENDS WITHOUT CRACKING . . . EVEN WITH NO PREHEATING!

Ordinary 0.060″ thick molybdenum broke at a 20° bend (see photo at left). The G-E "HD" sheet of same thickness shows no sign of cracking at 90°. Actually this new G-E Moly Sheet is so ductile you can bend it up to 180° without damage!

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GENERAL ELECTRIC

Personals . . .

Raymond M. Bluck and **Roy A. McKinnon** have been promoted to project engineers in the Tapco Group of Thompson Ramo Wooldridge, Inc., Cleveland. Since joining TRW in 1956, Mr. Bluck has concentrated on design for producibility of high-temperature and air cooled jet engine components and reinforced plastics. Mr. McKinnon joined TWR in 1955 and has been serving as technical liaison on the Arcogel fuel research and development program which he will now direct as project engineer.

Don B. Jugle has joined the staff of the Argonne National Laboratory, Lemont, Ill., as an assistant metallurgical engineer in the metallurgy division. He received his bachelor of science degree in metallurgical engineering from Columbia University in June, and spent the summer of 1958 at Argonne as a student aide.

Morris Kibrick, a metallurgist for Purolater Products, Inc., Rahway, N. J., was awarded the 1959 product design award of *Materials in Design Engineering*. The award, "for imaginative and progressive use of engineering materials in product design", was made for his design of a new fibrous porous metal filter disk.

Bill Floroplus, secretary of the South Florida Section of A.W.S. and a member of the S.N.T. executive board, is currently employed in field construction work for Bechtel Corp. at Port Everglades, Fla.

Jack H. Powers has been named supervisor of metallography at Adamas Carbide Corp., Kenilworth, N. J. Formerly associated with the metallurgical laboratories of the commercial atomic power department of Westinghouse Electric Corp. in Pittsburgh, Mr. Powers brings to his position 25 years experience in powder metallurgy, most of which were spent in research and development work on tungsten carbide at Firth Sterling.

John E. Bevan is now foundry metallurgist with Pangborn Corp., Hagerstown, Md. Prior to accepting this post, he was plant metallurgist with J. I. Case Co., located in Rockford, Ill.

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Progress in Explosive Forming

Digest of "High Energy Rate Metal Forming", by A. F. Watts and Glen N. Rardin, Lockheed Aircraft Corp., Burbank, Calif. Presented as a progress report under Contract No. AF 33(600) 35543 ASC Project No. 7-588.

WHAT HAPPENS to metals during explosive forming and what are the effects of the process on the mechanical properties of the metals which have been formed? These questions have prompted extensive work by researchers. In a broad program sponsored by the Air Force, engineers and scientists at Lockheed Aircraft Corp. have been investigating the effect of explosive forming on four alloys (VascoJet 1000, AM 350, 6% Al, 4% V titanium and 8% Mn titanium) which are known to be difficult to form by conventional methods. Ultimate aim of the work, which involves both basic and fundamental studies, is to apply the knowledge which is gained to explosive forming of airframe parts.

The test program was set up to study the influence of certain variables on explosive forming in dies of simple shape, the principles of free forming, and the effect of high strain rate on mechanical properties of metals.

Basic experience in die forming was gained by making cups from annealed VascoJet 1000 blanks, 0.025 in. thick. Cups were formed by exploding charges at a given distance above hemispherical dies 2.5 in. in diameter and 1.25 in. in depth (Fig. 1). Exploratory tests demonstrated that when the explosive wave travels through air to the workpiece, the dispersion of energy cannot be satisfactorily controlled. Reflectors placed above the charge to direct the energy increased the draw depth for the same weight of explosive, but the formed cups, although hemispherical in shape, did not fill the die. Usually each was either irregular in form or contained a nipple at its apex.

Similar tests were made to determine the effect of a vacuum in the die cavity. Here again the cups were not formed to the limits of the die. Because of this, it is felt that the vacuum tests were inconclusive. It is probable that vacuum is beneficial only when the workpiece is very close to the bottom of the die.

Lubrication (Dow Corning M-33) of the blanks was also tried with no increase in draw depth. Changing the stand-off distance (the distance between the charge and the workpiece) gave poorer results. As the

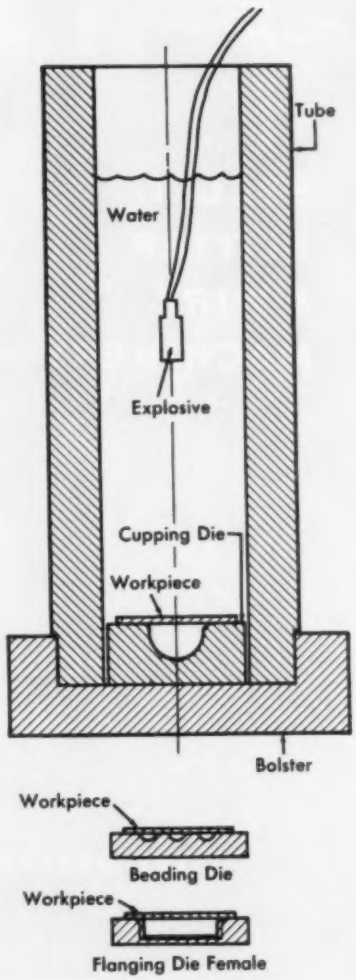
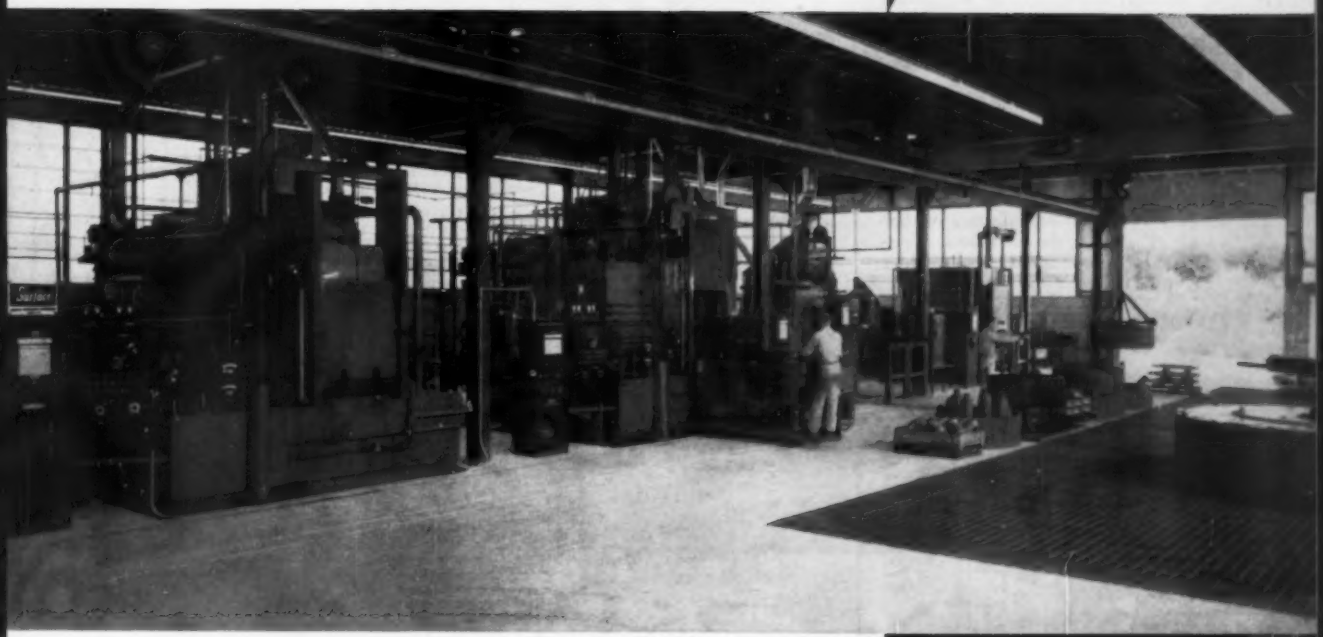


Fig. 1 – Tooling Setup Used in Explosive Forming of Cups and Beads

stop temperature variations in high density loads with SURFACE POWER CONVECTION



Exceptional uniformity and speed of heat treating, regardless of load density, help make a consistent profit-maker of this mechanized line of Surface batch-type furnaces at The Milwaukee Gear Company.

Because of Surface Power Convection, Milwaukee Gear has much greater metallurgical control and uniformity of product than ever before. High-velocity wind penetrates the tightest loads; assures uniform heat transfer whatever the size, shape, or alloy of the work.

Carburizing case depths are hit right on the button which vary from a few thousandths to 3/16 of an inch. This unusually flexible standard rated furnace line consists of two Super Allcase® furnaces, a horizontal draw furnace, spray washer, DX® and RX® gas generators, and Autocarb® signalling dewpoint controller.

Surface Power Convection cuts cycle times to a fraction.

These advantages only suggest the profitability of Surface Power Convection. Ask your Surface representative to describe the most important development in convection heat transfer in 20 years.

Write for Bulletin SC-182.

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Surface

Table I – Mechanical Properties of Control and Prestrained Specimens*

Alloy	Tensile Strength	Yield Strength	Elongation in 2 In.
	Control Coupons		
VascoJet 1000	270,000 psi.	222,100 psi.	5.5%
AM 350	207,000	165,000	13.0
Ti(8% Mn)	152,000	145,000	20.5
	Prestrained Coupons		
VascoJet 1000	294,300	287,700	2.5
AM 350	211,800	192,600	8.5
Ti(8% Mn)	161,400	158,000	10.00

*Coupons were 0.024 in. thick.

distance was increased from 2.5 in., heavier charges were needed to obtain a given draw depth. The combination of greater stand-off distance and heavier charge resulted in poor blast pressure distribution and cups were generally irregular in contour. There was no correlation between the test variables and the shape of the cups.

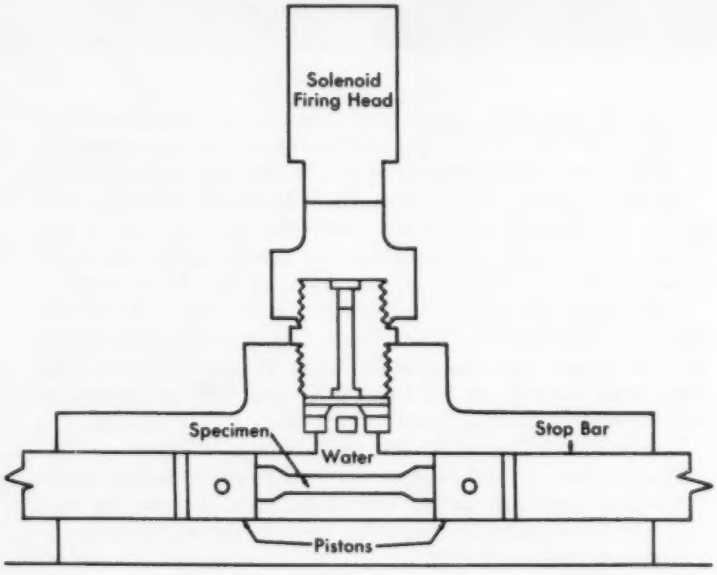
Water Improves Results

The most important improvement in forming occurred when water was used as the transfer medium between the charge and the workpiece. Cups had excellent symmetry, but were generally conical in shape rather than hemispherical as in the tests with air as the transfer medium. Flanges were also wrinkled more and, as before, cups did not fill the cavity.

Charge Reduced

Initially, explosive forming of VascoJet 1000, 0.025-in. thick with 2.5 g. of explosive Composition C-3 at a stand-off distance of 10 in., caused the workpiece to rupture. Consequently, only a blasting cap and tetryl pellet were used in subsequent tests. Stand-off distance was varied from 3 to 10 in. Maximum draw depth (0.82 in.) occurred when the explosive was detonated 6 in. from the workpiece. The effect of stand-off distance on draw depth

Fig. 2 – Details of Internal Tester in Which Tensile Specimens Were Prestrained. Gunpowder is burned in the firing chamber until the expanding gases rupture a metal disk. Pressure is then transferred to the water which acts against the pistons. Strain rates are determined by using pin contactors (to measure piston velocity) and strain gages.



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HOT WORK DIE STEELS

for your applications that ask the most of quality on the job

These are the leading die steels for hot work wherever high temperatures make life hard on dies. Their stamina, stability and resistance to wear have made them fixtures in the modern die shop—first choice consistently by men who know *first quality* in steel.

FORGE-DIE

14% tungsten. High resistance to softening at high temperatures. For piercers, punches, hot forming dies.

HOTFORM

Most widely used hot work die steel. 5% chromium. High strength, toughness, resistance to heat checking. Die casting, extrusion, and hot forging dies; mandrels, etc.

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10% tungsten. High resistance to high temperatures. Punches, nut piercers, brass forging dies, etc.

HOTPRESS

Tungsten die steel with added high temperature toughness. Dummy blocks, upsetting dies, extrusion dies.

Vanadium-Alloys Steel Company
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Explosive Forming . . .

of the 0.025-in. annealed VascoJet 1000 is shown below*:

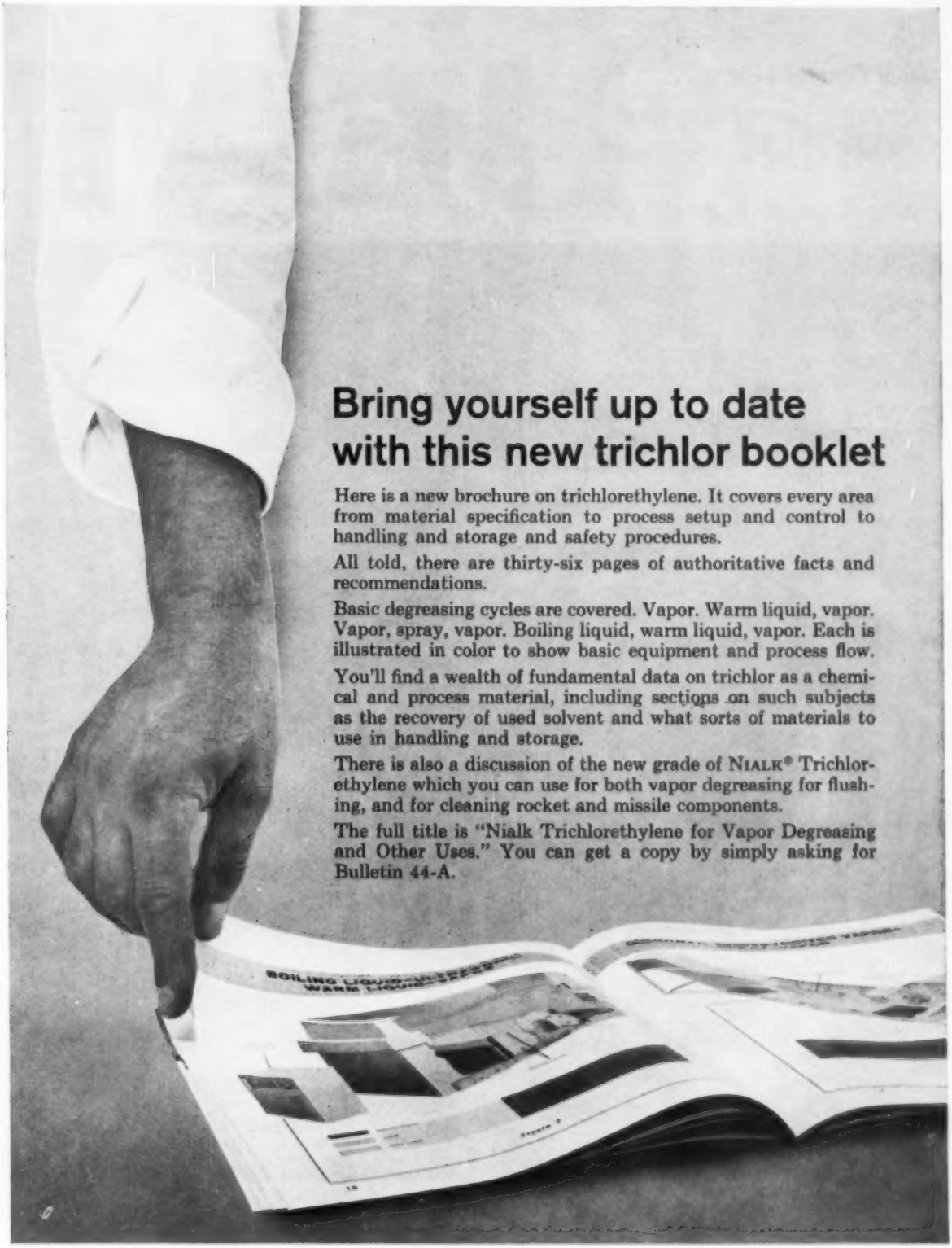
Stand-Off	Draw Depth
10.0 in.	0.71 in.
10.0	0.75
8.0	0.76
6.0	0.82
6.0	0.79
4.0	0.77
3.0	Fractured

Similar tests were conducted with beaded dies 0.25 in. deep. In the particular setup, the best stand-off distance for maximum draw depth was again 6 in. Each formed piece contained cracks at the edges of the beads. At each bead apex next to the die there was some evidence of surface burning. This is attributed to the temperature increase in the air trapped between the workpiece and the die. When vacuum was applied to this region, no burning was observed.

Free Forming Tests

Free forming yielded some interesting results on the response of the four alloys to explosive forming. Except for preliminary work, all tests were conducted with water serving as the transfer medium. Air again was ineffective; irregular cups were formed and heavy charges were required. With stand-off distance, head of water, and die shape held constant, tests were conducted on blanks of all four alloys. Only the weight of explosive was varied until in each test series an increase in the charge destroyed or fractured a blank. Elongation of the metal during forming was determined by measuring the increase in distance between grid lines which were superimposed photographically on the blanks. Dynamic elongation values can be compared with those obtained from cups formed at slower strain rates by a conventional method in a double action tool. Tests indicated that for a gage length of 0.1 in. the dynamic elongation during explosive forming is considerably less than obtained in the conventionally formed cups. Deeper cups can also

* Tests were performed in a steel container filled with water (24-in. column) using a 2.5-in. diameter hemispherical die, and blasting cap and tetryl pellet explosive charge.



Bring yourself up to date with this new trichlor booklet

Here is a new brochure on trichlorethylene. It covers every area from material specification to process setup and control to handling and storage and safety procedures.

All told, there are thirty-six pages of authoritative facts and recommendations.

Basic degreasing cycles are covered. Vapor. Warm liquid, vapor. Vapor, spray, vapor. Boiling liquid, warm liquid, vapor. Each is illustrated in color to show basic equipment and process flow.

You'll find a wealth of fundamental data on trichlor as a chemical and process material, including sections on such subjects as the recovery of used solvent and what sorts of materials to use in handling and storage.

There is also a discussion of the new grade of NIALK® Trichlorethylene which you can use for both vapor degreasing for flushing, and for cleaning rocket and missile components.

The full title is "Nialk Trichlorethylene for Vapor Degreasing and Other Uses." You can get a copy by simply asking for Bulletin 44-A.

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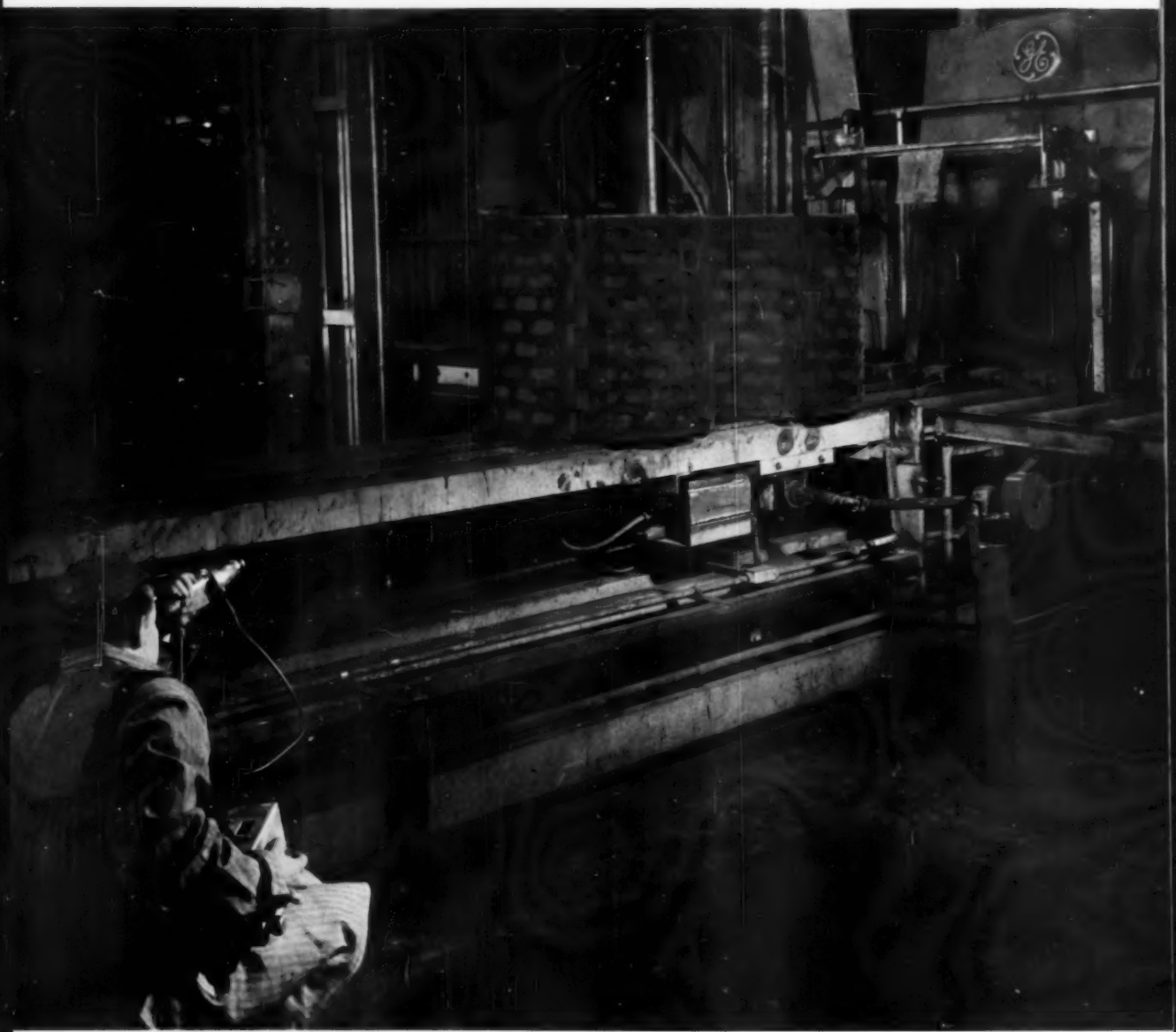
HOOKER CHEMICALS PLASTICS

From General Electric . . .

HEAT



Castings automatically transferring from high temperature furnace to other pearlitic annealing equipment at Marion Malleable Iron Works, Marion, Indiana.

GENERAL ELECTRIC

ONE FURNACE SYSTEM DOES SEVEN JOBS

General Electric "systems" design combines furnace, temperature and atmosphere controls, and materials handling to cut annealing cycle 75%, provide added flexibility, and lower processing costs

When you bring your heat processing problems to General Electric, our engineers will give you what you want and need. Whether it's gas or electric, a small batch furnace or a complex, automated system, you need go no further.

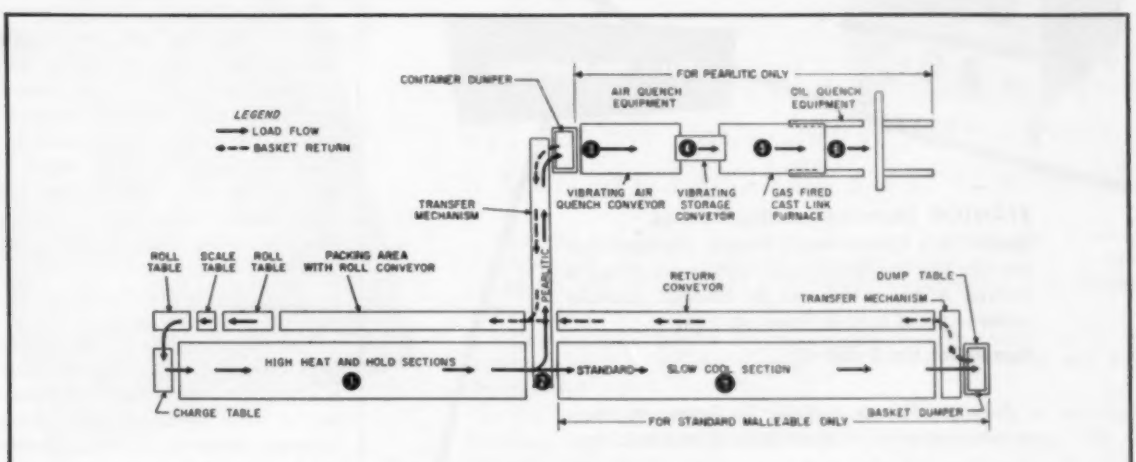
For example, when the **Marion Malleable Iron Works of Marion, Indiana,** set out to acquire "the most modern heat treating equipment which would be very flexible and produce highest quality at a nominal cost," they chose General Electric. The result: a complete system (at left and below) with integrated temperature and atmosphere controls and automatic handling equipment. With one packer and one operator, this system produces 1000 tons of standard malleable iron per month. Or 800 tons of pearlitic and 200 tons of standard malleable per month. Or, with the addition of a separate high temperature furnace, 1000 tons of standard malleable and 800 tons of pearlitic malleable per month. And depending on the type of material required, each of the seven automatic functions (below) can be varied as desired.

In addition, the automatically-controlled annealing cycle has been cut from five days to just 40 hours—a 75% speed-up! Quality is up, and controlled atmosphere (Neutralene) has practically eliminated surface decarburization and assures maximum alloy life of furnace components. Fuel costs are less because of shorter cycles, and labor costs are down. Flexible enough to produce either ferritic or pearlitic malleable, the furnace can even be left loaded and unattended over weekends to allow five-day operation.

As a result, Marion Malleable can offer a higher quality product and rapid delivery to its customers, and thanks to the savings of the G-E system, at a very nominal cost.

If you're planning a new heat processing installation or modernization—gas or electric, large or small, with or without atmosphere and materials handling equipment—it will pay you to contact your General Electric Apparatus Sales Office. General Electric Co., Section 721-26, Schenectady 5, N. Y.

GENERAL ELECTRIC



ONE SYSTEM, SEVEN JOBS. This complete heat processing system, designed and built by General Electric, automatically (1) heats and holds at temperature, (2) transfers and dumps, (3) air quenches, (4) reloads, (5) reheats, (6) oil quenches, or (7) slow-cools 1000 tons of castings per month with maximum flexibility. Note that two heat processes—pearlitic and standard malleable—can take place simultaneously, depending on mixture of material being processed, and yet work baskets are handled automatically from the time they are placed on the entrance table until the entire cycle is completed.

Explosive Forming . . .

be formed by the conventional method. Thus it appears that explosive forming is not a suitable process for making deep-drawn parts.

Temperature Increases

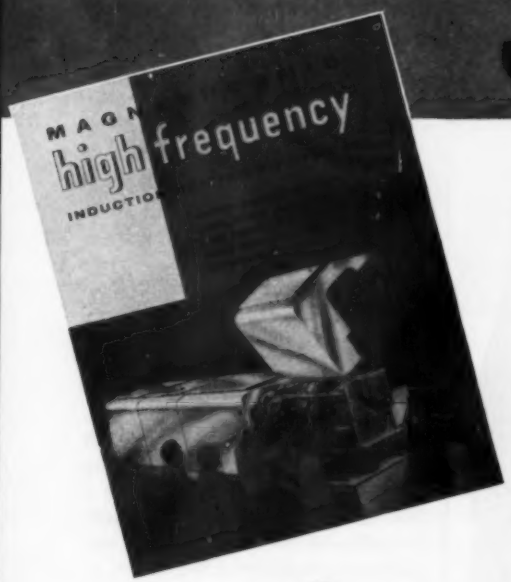
Attempts were made to determine temperature increases which were experienced by VascoJet 1000 sheet during explosive forming. Although the thermocouple probes broke from the workpiece almost simultaneously with the impact of the explosive shock, they remained attached to the sheet long enough (about 6.8×10^{-4} sec.) in one test to permit some measurements to be taken during most of the forming process. Maximum temperatures recorded were: workpiece center 420° F.; ½ in. from center 670° F.; 1 in. from center 360° F.

Impact Velocity

The effect of explosive forming on formability is another important aspect which was investigated. Past work has suggested that there is a maximum forming velocity above which brittle fracture of the metal will occur. But the critical impact velocity, determined, for example, with high speed tensile impact machines, cannot be applied directly as a measure of the limiting forming velocity. Rather, a complexity of factors such as part geometry, plastic deformation, work hardening, and dynamic stress concentration assume equal importance in explosive forming. For this reason, it has been difficult to correlate forming velocities encountered in explosive forming with published critical impact velocities obtained by high speed impact tests.

Strain Rate

The determination of strain rate from forming velocity measurements is a step towards better understanding of some of the factors which influence dynamic ductility. During the forming of 6-in. diameter hemispherical cups, the strain rates ranged from 46 to 407 in. per in. per sec. These values are based on the assumption that the strain is uniform over the time interval of the forming process. As yet, the data cannot be related directly with



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Trenton 7, New Jersey

Explosive Forming . . .

dynamic elongation, but a knowledge of strain rates experienced during explosive forming may prove to be helpful by permitting comparisons with similar data obtained during forming by more conventional methods.

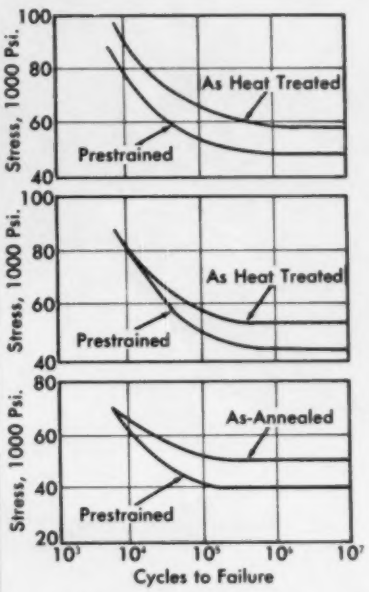


Fig. 3 — S-N Curves Indicate That High Strain Rates Reduce Fatigue Strength. Data was obtained from specimens prestrained in tooling shown in Fig. 2.

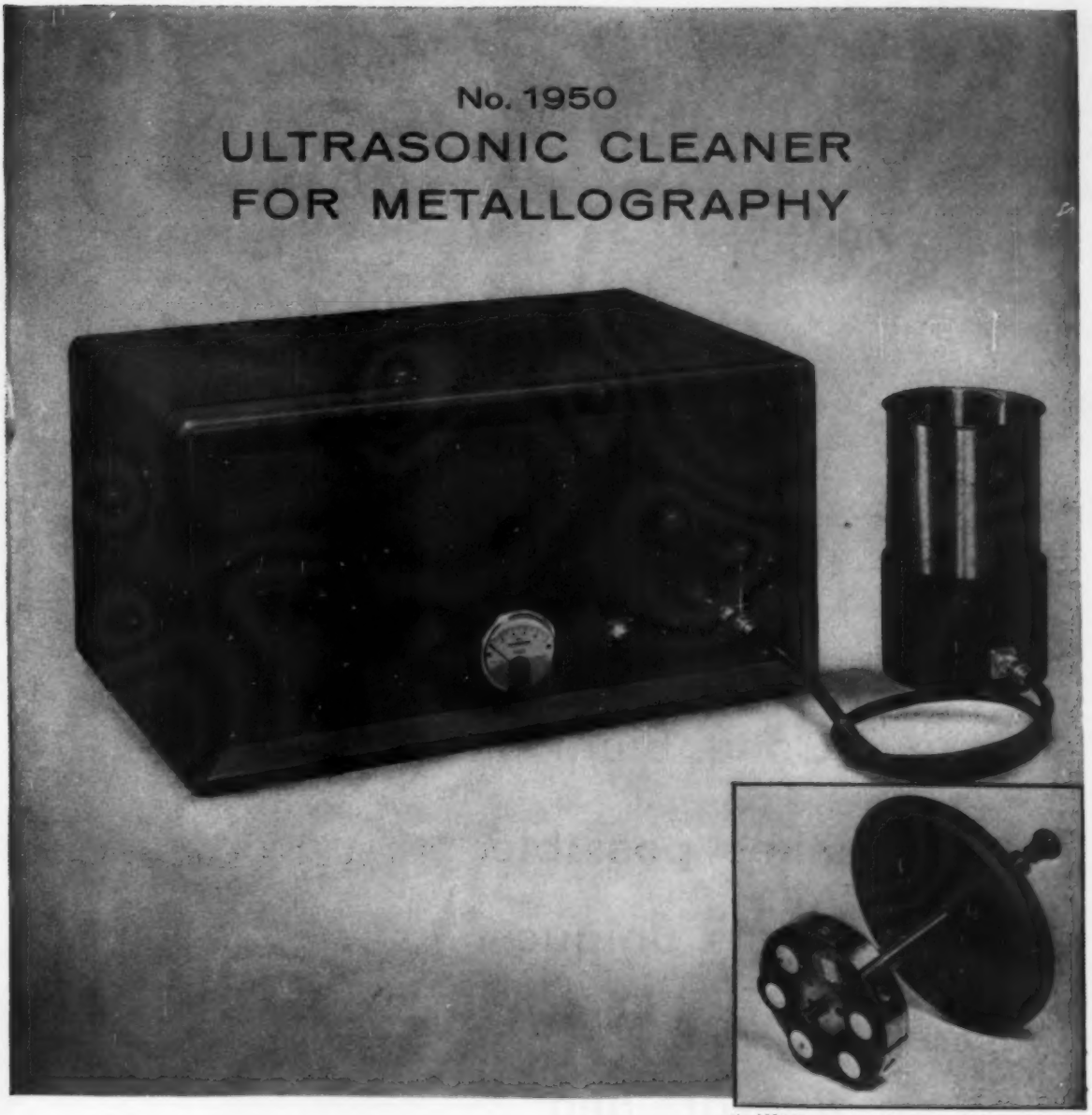
Further investigations of the effect of strain rate on mechanical properties were made with tensile specimens of the four alloys which were prestrained (Fig. 2) at rates corresponding to those experienced in the previous tests with cups. For any particular alloy, cold rolled, prestrained and control samples (as heat treated or annealed) were all of equal hardness. Prestraining improved strength, but resulted in a loss of tensile ductility. Tensile properties of some of the control and prestrained specimens are shown in Table I on p. 142.

Normally it can be expected that fatigue strength will improve with cold working. However, specimens which were explosively prestrained suffered a considerable reduction in endurance limit (Fig. 3). R.G.D.

(*More digests on p. 152*)

No. 1950

ULTRASONIC CLEANER FOR METALLOGRAPHY



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Gases in Low-Carbon Steel

Digest of "Gas-Metal Reactions During Box-Annealing of Low-Carbon Steel", by R. M. Hudson and G. L. Stragand, Preprint No. 150, 1959.

DURING COMMERCIAL box-annealing of low-carbon steel, a considerable volume of gas is evolved. This causes changes in the furnace atmosphere, and, in tightly coiled strip, gas composition may be different between the surface and center of the coils.

This paper describes experiments in which gas evolution from steel during elevated-temperature vacuum annealing was studied, and in which gases were sampled from within tightly wrapped coils during annealing. Composition of the furnace gas during annealing is different from that supplied to the furnace, and the gas mixture within a coil is different from both of these. Carbonaceous gases (CO and CO_2) in the evolved gas are derived from the steel itself. However, larger amounts of these along with hydrocarbon gases are encountered when the steel surface contains appreciable amounts of organic material, such as cold reduction lubricants.

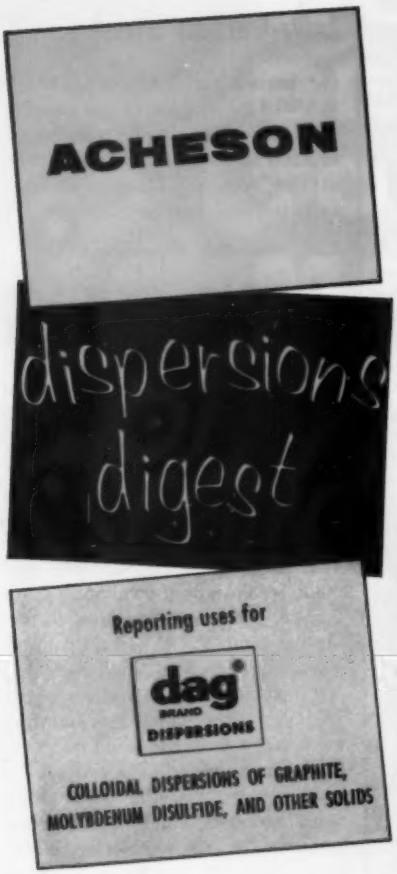
The important effect that annealing gas composition can have on the surface properties of steel is indicated by previous investigations, concerning the effect of annealing atmosphere on the rate of acid pickling of tin-plate steels.

Degassing Procedure

Hot extraction degassing experiments were caried out in which 3 × 2 × 0.01-in. strip samples were heated in vacuum, and the evolved gases were collected and analyzed. Strip samples in the hot rolled, pickled, as cold reduced, box-annealed and normalized conditions were tested. Three hot extraction methods were used for 60 to 90 g. samples, as follows:

1. Samples were heated to 1000° F., and soaked 30 min. This was followed by successive reheats at 50° F. increments and 30 min. soak periods, up to 1350° F. The total gas was collected, and samples were analyzed.

2. Samples were heated similarly, in 100° F. steps, with 30 min. soak-



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'Prodag' application on forging presses at Mueller Brass Company has saved between $15,000 and $17,000 annually for the past fifteen years. These impressive savings earned by this Port Huron, Michigan company — the world's largest producer of brass and bronze forgings — have been realized in many areas.

Previously, crank forging pressmen at Mueller swabbed the dies between each press stroke. Mueller designed their own spray apparatus, both manual and automatic, to lubricate lower and upper dies simultaneously. Time studies have shown that spraying has effected a five percent-per-pound economy over the swab method.

Spray application of 'Prodag' at Mueller Brass Company has resulted in impressive production savings.

Even more importantly, by using Acheson's 'Prodag' — a dispersion of graphite and water — diluted 1:35, Mueller has gained longer die life, reduced the percentage of scrap loss, and has obtained a better finish on their forgings. According to Mr. O. M. Hanton, Chief Forging Engineer for Mueller, "with 'Prodag' we get the right amount of lubricant on the die. Swabbing resulted in too much lubrication at one place or another in the die cavity, resulting in either a ruptured die or a defective part. Previously, every forging produced had to go to the grinding department. And grinding is one of the most expensive operations in a forge shop."

In producing deep-cavity forgings, or products which demand much smaller tolerances, Mueller uses 'dag' No. 3 — another of Acheson's graphite-water base dispersions. If you have a forging lubrication problem it will pay you to call in your Acheson Service Engineer or write for Bulletin No. 426.

'dag' 35, brush-applied to the slides of this rollover machine, increases machine life for this midwest foundry.

An expensive foundry problem was solved for the D. J. Murray Manufacturing Company, Wausau, Wisconsin, with the use of Acheson's 'dag' 35 — colloidal graphite in an alkyd resin solution. Slides on the huge rollover machine installed in their foundry division, previously lubricated by first a dry graphite and then rosin, were becoming deeply scored as a result of its 90-cycle-a-day operation in the handling of bench and floor molds.

The scoring and machine vibration was so severe that according to Maintenance Foreman, Ben Sayles, "we could see that the life of the machine was going to be very short if we continued this method of lubrication." Coating the slides daily with 'dag' 35, improved machine operation immediately. The scoring all but disappeared. After two years of application with this Acheson dispersion, no repairs have been necessary and none are foreseen. Since the entire production of their grey iron sand slinger line — some 60 tons of material in 8 hours — goes through this machine, the downtime avoided represents an important savings to the company.

For additional information, write for Acheson Bulletin No. 425. Address Dept. MP-119.

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Low-Carbon Steel . . .

ing periods, at 1000 to 1600° F. followed by analysis of gas samples.

3. Individual samples were heated to 1200 to 1600° F. and held 24 hr. at temperature. Gases were then collected and analyzed.

Coil Annealing Experiment

In other tests, tightly coiled steel strip was box-annealed with a protective atmosphere (inlet composition: 5 to 6% H_2, less than 0.1% H_2O, remainder N_2.) The load charged for each test was three coils, and the bottom (test) coil contained radial, 2-in. diameter holes, drilled for depth of 5 in. at the center and 3 in. from one edge. The holes were sealed and connected to a vacuum system. Provision was made for flushing the volume (about 225 cc.) with mercury prior to taking gas samples. When the annealing furnace was fired, the tubing and test hole were evacuated for about 15 min. after which gas samples were taken from the edge and center position periodically during the box-annealing cycle. Gas analyses were carried out chiefly by the Orsat method. Several samples were also taken for mass spectrometric analysis, from the edge, center and coil-surface positions. A continuous temperature record near the furnace gas inlet was obtained. Temperatures in the hole locations were also measured. Samples of inlet and outlet gas from the furnace were taken during the investigation and dew-point determinations were made by the dew-point cup method. The steel coils used for the tests were about 35 in. wide and 0.010 in. thick. Each coil weighed about 6000 lb. They were tested in the following conditions: hot rolled, pickled, cold reduced, electrolytic alkaline-cleaned, uncleaned, and after subjecting to two cleaning cycles.

Five coil tests were carried out, one of which was a re-anneal of the first specimen.

This experimental method allowed study of the within-coil gas composition during annealing cycles, and of changes in the furnace gas composition occurring during box-annealing. Information on gas composition within the coils is of interest because the observed changes

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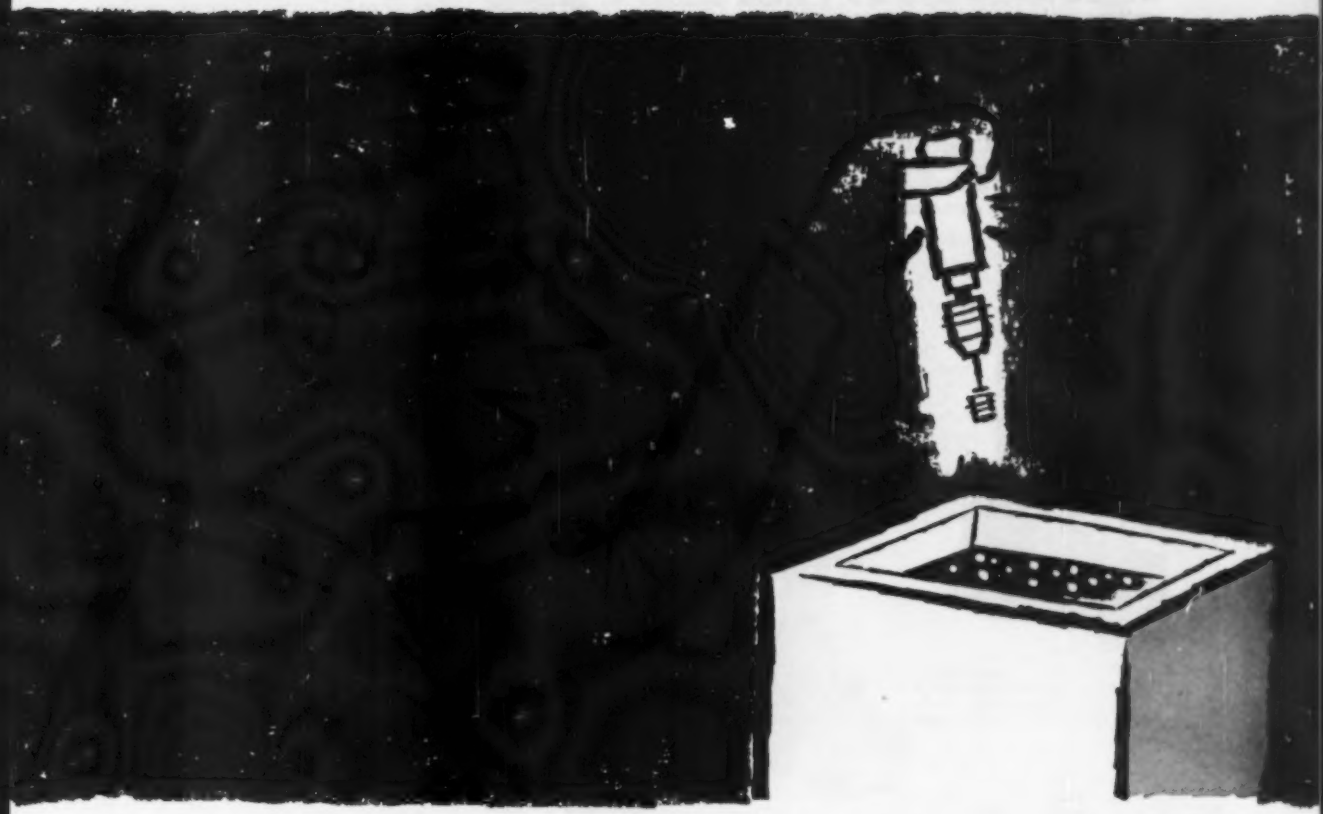

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Low-Carbon Steel . . .

in furnace gas composition can occur only through reactions of annealing gas components, with the steel, with surface organic contaminants, by reaction of oxides in steel with carbides, and by desorption of hydrogen from steel.

The composition of the furnace gas during annealing is different from that supplied to the furnace. It generally contains more CO, H_2, CO_2 and less H_2O. The gas mixture within a coil is different from the original furnace gas atmosphere and from the discharged outlet gas. Gas samples taken within the coil contain more CO, H_2 and CO_2 than either the input or output furnace gas. In instances where cleaning has been omitted (particularly when cold reduction lubricants remain on the steel surface), hydrocarbons are detected. Carbonaceous gases (CO and CO_2) in the evolved gas are derived from the steel itself although higher amounts of these and hydrocarbon gases are found when the steel surface contains appreciable amounts of organic materials.

D. E. PARSONS

Activation Energies for Creep

Digest of "Activation Energies for Creep of an Alpha Solid Solution of Magnesium in Aluminum", by N. R. Borch, L. A. Shepard and J. E. Dorn, ⊕ Preprint No. 117, 1959.

THE FUNDAMENTAL creep behavior of an aluminum alloy containing 2.82% Mg was studied over the temperature range of −310° F. to 1200° F. (the melting point), and the results were analyzed in terms of various well-established deformation theories and mechanisms. Apparent activation energy for creep was used as the criterion for evaluating the results of creep tests.

Over the range where only one thermal activation process controls the creep rate of a metal, the activation energy is independent of temperature. When, however, several independent creep processes operate simultaneously, the activation energy is the weighted average activation energy of all the operative processes. In this event, the observed

Creep . . .

activation energy is dependent on the test temperature. In such instances as these, it is advisable to distinguish this weighted activation energy by referring to it as the "apparent activation energy".

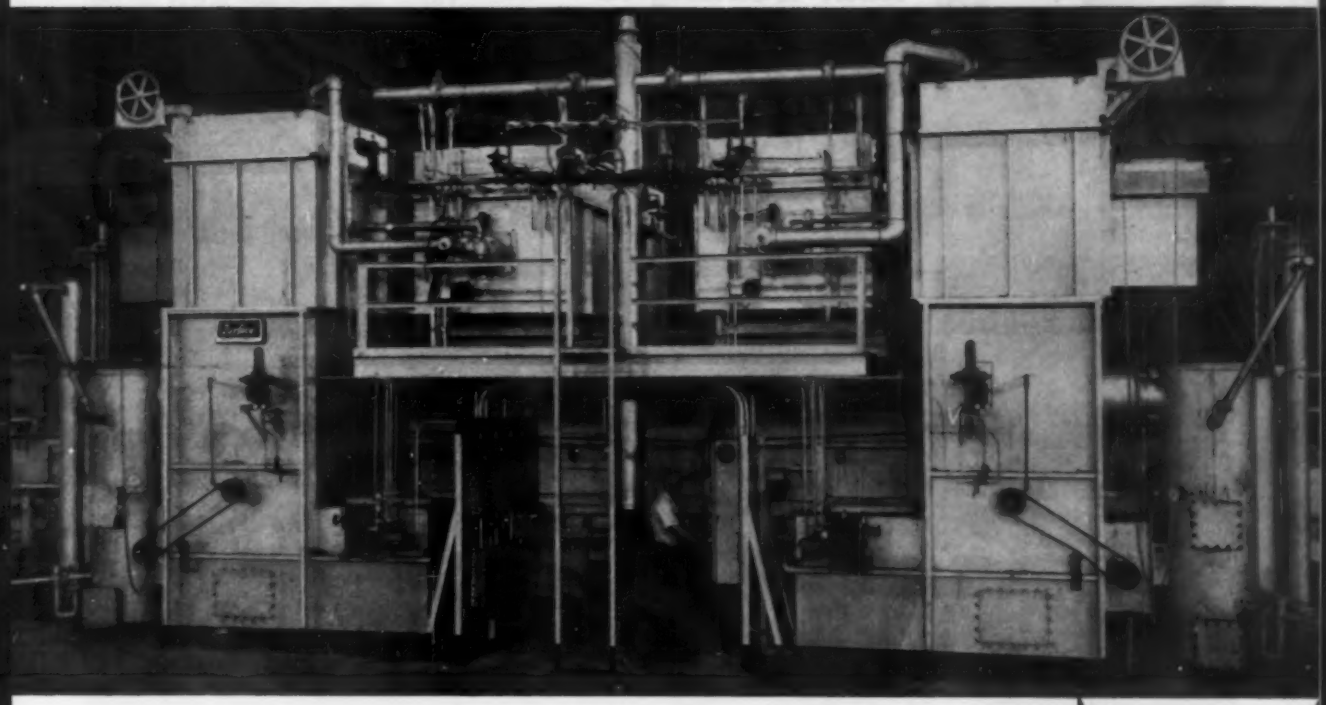
The results obtained on the 2.82% Mg aluminum alloy clearly indicate that a number of processes are operative in the creep of this material. Actually, the results fall into three distinct groups depending on the temperature range.

Above about 435° F. the activation energy for creep in the alloy investigated remains constant up to the melting point at 35,500 cal-mole, and is the same as for pure aluminum. This value is also equal to the activation energy for self-diffusion of aluminum. These facts, coupled with the observation that extensive polygonization takes place in this temperature range, lead to the conclusion that high-temperature creep is controlled by a dislocation climb mechanism as suggested by previous investigators.

From −22 to 255° F., pure aluminum creeps with an activation energy of 28,000 cal-mole which the authors interpret as being associated with a process of cross-slip. The Al-Mg alloy, however, shows only this activation energy in the much narrower range of 220 to 255° F.

Between −310 and −22° F., the activation energy for creep both in pure aluminum and in the 2.82% Mg aluminum alloy increases from about 4000 cal-mole to 28,000 cal-mole. This change in activation energy is rationalized in terms of two processes: (*a*) cross-slip and (*b*) Peierls process. The cross-slip process has been discussed above. The Peierls process is associated with an activation of about 3400 cal-mole. Thus as the temperature increases from −310 to −22° F., there is a gradual transition from a condition where Peierls process dominates to a condition where the cross-slip process dominates.

Between −22 and 220° F., where pure aluminum exhibits a constant activation energy of 28,000 cal-mole, the 2.82% Mg aluminum alloy shows an activation energy rising to a peak of greater than 80,000 cal-mole at 120° F. and then falling again to the 28,000 level at 220° F.



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Creep . . .

The high activation energy in this temperature range is ascribed to Cottrell locking, the activation energy being the sum of that for cross-slip and unlocking of dislocations.

T. E. LEONTIS

Steels Containing Columbium

Digest of "The Effect of Small Columbium Additions to Semi-killed, Medium-Carbon Steels", by C. A. Beiser, Preprint No. 138, 1959.

THIS INVESTIGATION deals with the effect of columbium and manganese on microstructure and mechanical properties of commercial and laboratory steels. Two series of laboratory steels were made containing 0.45 and 1.5% Mn, respectively (about 0.2% C and 0.07% Si). In each series, ingots were cast with columbium contents varying from 0 to 0.1%; these ingots were hot rolled to 0.6 in. plate. For comparison, commercial steels of comparable analysis were obtained as hot rolled plate, varying in thickness from ⅜ to 1½ in. All materials were studied in the as-received, hot rolled condition and after normalizing for 1 hr. at 875° C. (1600° F.).

As expected, grain sizes decreased as columbium content increased. Grain sizes of hot rolled materials were reduced more than one A.S.T.M. number for columbium addition up to 0.1%. The grain-refining effect was still present after the normalizing treatment at 875° C. (1600° F.) which reduced the grain sizes by about two A.S.T.M. numbers.

Columbium raised yield and tensile strength, and reduced ductility. The most effective additions were at the low end of the range. For example, an addition of 0.03% Cb raised the yield strength by about 15,000 psi. and the tensile strength by 10,000 psi. After normalizing, however, the effect was much less marked, although the yield strength was improved somewhat for columbium additions up to 0.03%. In the laboratory series, manganese raised yield and tensile strengths, and improved ductility slightly.

Charpy V-notch tests on all hot rolled steels showed that the ductile-

Keep high alloy melts CLEAN

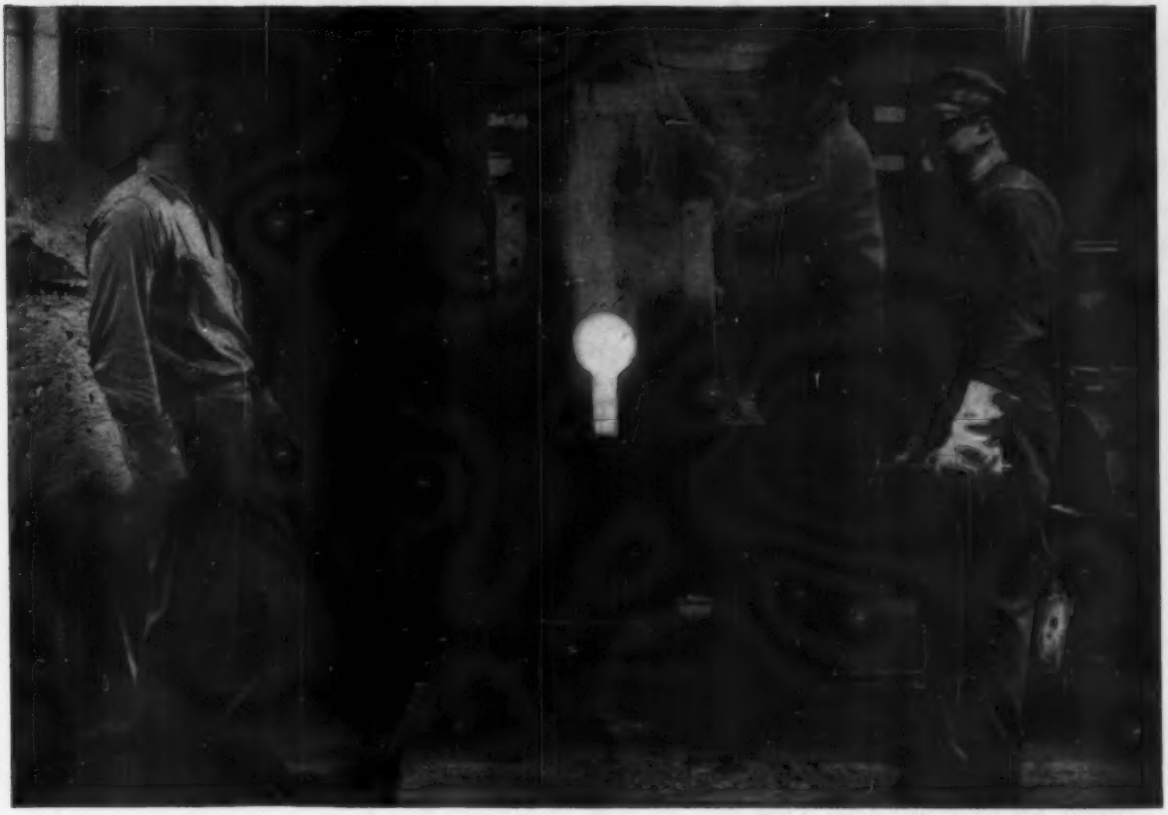

Photo courtesy Arwood Precision Casting Corporation.

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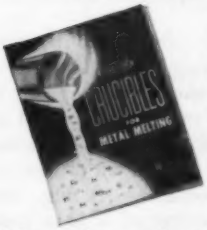

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Cb in Steel . . .

to-brittle transition temperature was raised (from about room temperature for 0% Cb) by approximately 10° C. (18° F.) per 0.01% Cb. The difference in manganese contents between the two laboratory series (1%) was effective in lowering the transition temperature by about 30° C. (54° F.). The effect of columbium was completely reversed by normalizing; the transition temperature was *reduced* by about 10° C. (18° F.) per 0.01% Cb. For example, a combination of 0.06% Cb and 1.5% Mn lowered the transition temperature from +10 to −68° C. (50 to −55° F.).

The marked difference in behavior between the hot rolled and the normalized steels could be explained by microstructure. Microscopic and X-ray examination revealed continuous carbide networks in the hot rolled steels; the normalized steels were relatively free of this embrittling carbide. This fact, taken together with the combined grain-refining effects of columbium and normalizing treatment, explains the differences in mechanical properties. In the hot rolled condition, the steels became stronger but more brittle with increasing columbium because of the increasing amounts of grain-boundary carbide. Normalizing removes the carbide and the grain-refining property of columbium. The addition then has its full effect in improving the impact behavior and (slightly) improving the tensile properties W. M. WILLIAMS

Stress-Relieving Aluminum Alloys

Digest of "The Thermo-Mechanical Method for Relieving Residual Quenching Stresses in Aluminum Alloys", by H. N. Hill, R. S. Barker and L. A. Wiley, Preprint No. 132, 1959.

A DIFFICULTY frequently encountered during the machining of a heat treated aluminum alloy part is the warpage caused by removal of stressed material. Residual stresses in such parts are a result of thermal gradients prevailing during the quenching portion of a heat treat operation. Such residual stresses are compression stresses on the surface

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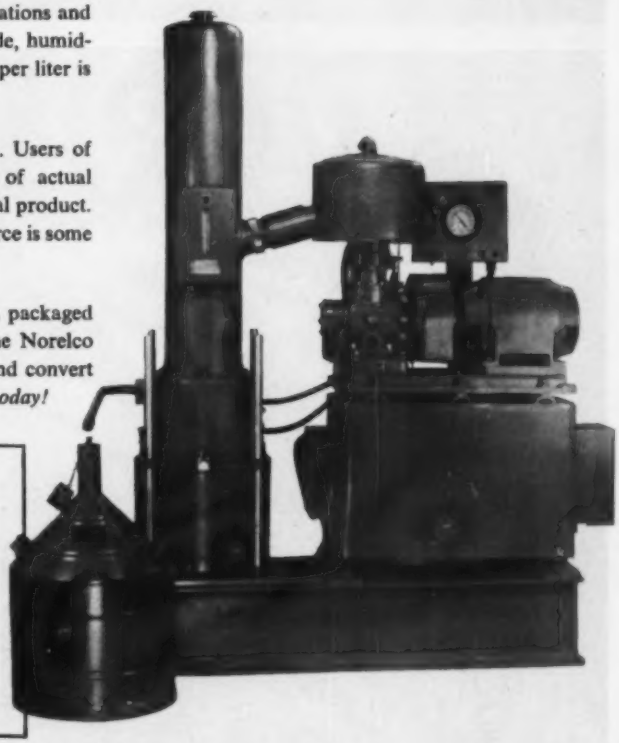

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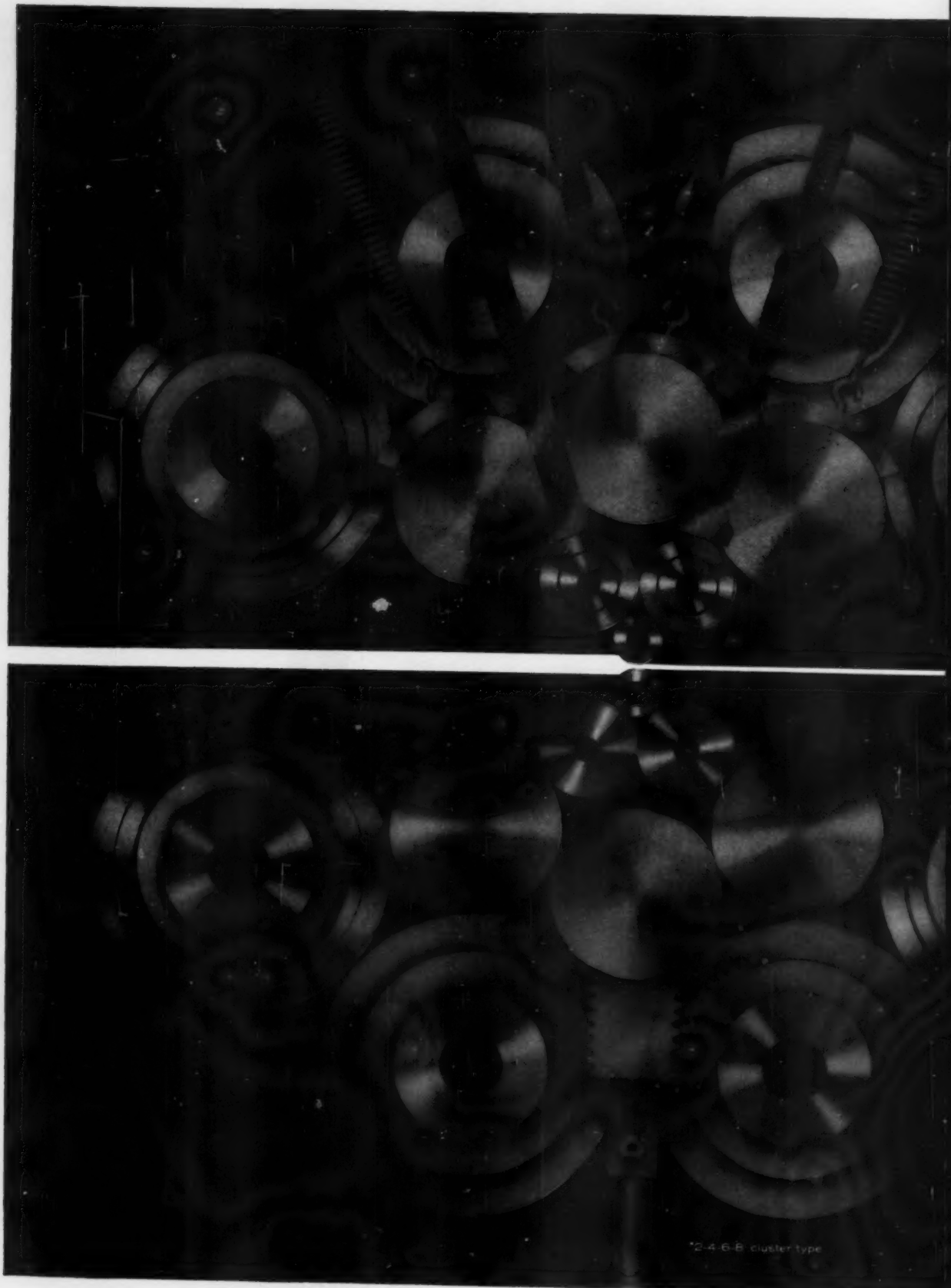
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Aluminum Alloys . . .

and tension stresses in the interior.

Relief of these residual stresses is frequently desired and is accomplished in material of uniform cross section by commercial methods of stretch relief. With such a treatment the material is sufficiently deformed plastically so as to relieve the differential strain by yielding. Compression may be applied to parts of more intricate shape to achieve the same effect.

Since the residual stresses are a result of thermal gradients, and since such stresses are compression on the surface and tension in the interior, it seems reasonable to assume that if reverse thermal gradients could be set up, reversed residual stress might be introduced which would act to cancel out the original residual stresses. This idea of such an "up-hill" quench is not new, but little was achieved in the past, apparently because the thermal gradients were not great enough.

A "thermomechanical" treatment has been developed to reduce the level of residual stresses in aluminum alloy parts that have been quenched from a solution heat treating temperature in such a manner as to introduce residual stresses of appreciable magnitude. The procedure is as follows:

1. After quenching, and before appreciable precipitation hardening has occurred, the part is cooled to a very low temperature. Cooling in liquid nitrogen (−320° F.) has been found to be most effective. (Earlier work generally involved cooling in dry ice to a temperature of around −100° F.)

2. The part is removed from the cooling medium, and all surfaces are blasted immediately with steam at relatively high velocity. (Earlier work used boiling water rather than steam.)

3. The part is then aged in the conventional manner for the specific alloy.

Such a specific treatment has been found to lower the residual stress level by 80% for aluminum alloy parts quenched in water, with no significant change in properties.

Experimental work for developing the treatment involved the use of 6 × 12 × 2-in. pieces cut from plate aluminum alloys 2014 and

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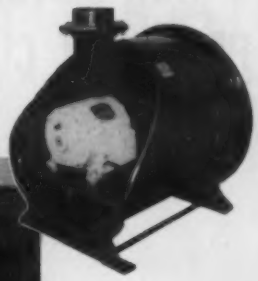

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Aluminum Alloys . . .

7075. Some work was done with samples ½ in. thick to investigate the effect of thickness. Thermocouples were located at mid-width and mid-length of the sample, and at different distances from the sample. A steam heating chamber was constructed and connected to a boiler operating at 175 psi. pressure. Residual stress diagrams were constructed from data obtained from sectioned samples. Variables that were investigated included (*a*) cooling temperature, (*b*) method of reheating, (*c*) yield strength of the material at the time of treatment (related to time after quenching), and (*d*) original residual stress state. Finally, a 7075 die forging, on which some success had been obtained in reducing residual stresses by "compression" treatment, was subjected to "thermomechanical" treatment for comparison purposes.

A range of cooling temperatures from −100 to −320° F. were investigated with the lowest residual stress level being achieved with the lower temperature.

Reheating methods, including boiling water and molten salt, as well as the steam blast, were investigated, but only the steam blast was found effective. Two features of the steam blast are of importance: (*a*) the heat of condensation of the steam, and (*b*) the blast to keep the condensate removed from the surface.

Since the thermal gradient during treatment must be great enough to produce local plastic deformation, the treatment must be applied before the yield strength has been increased by any aging, natural or artificial. It is significant that relatively small differences in yield strength at the time of treatment produce rather large differences in the resulting residual stress range.

Since the purpose of the treatment is to introduce residual stresses opposite in direction to those introduced by the quench, it was possible, by thermomechanically treating an annealed stress-free sample, to produce tension stresses on the surface and compression stresses in the interior. This latter point demonstrates that the treatment is not to be used indiscriminately.

D. E. GRIMM

Welding Magnesium-Thorium Alloys

Digest of "The Arc Welding of Wrought Magnesium-Thorium Alloys", by L. F. Lockwood and Paul Klain, *Welding Journal*, Vol. 37, June 1958, p. 255s-264s.

A METALLURGICAL ACHIEVEMENT of major significance during recent years has been the development of lightweight high-strength magnesium alloys containing small additions of thorium, zirconium and magnanese. These alloys, possessing useful strength as high as 900° F., have now been studied to determine their welding characteristics. The present paper reports on the experimental results of test welding three such alloys, HK 31 A, HM 21 XA-T 8, HM 31 XA.

Welding techniques included inert-gas-shielded tungsten-arc processes, with and without filler rods of varying alloy composition. The power source was an a-c. high-frequency stabilized unit. No precautions other than a suction hood for fume removal were necessary.

Welds were evaluated by static tensile, creep and corrosion testing at a variety of temperatures, under conditions conforming to testing standards. Test specimen configurations included circular bead and confined triangle arrangements.

Thorium-containing alloys exhibited no cracking tendency, and were readily welded. Welding reduced the strength as much as 30% at room temperature, but welds and base metal exhibited comparable physical properties at elevated temperatures. Heat treating weldments did not appear to alter physical properties significantly.

Alloys of dissimilar composition were joined satisfactorily, and wrought components were welded to cast structures without undue difficulty. Some strength differences were observed as a function of welding rod composition; the optimum alloy composition depends upon the ultimate service conditions.

The paper presents an extensive collection of tensile and creep data, and includes a number of photomicrographs of typical alloy and weldment structures.

J. L. WYATT

Stringers in Zircaloy-2

Digest of "Metallographic Study of Stringers in Inert Atmosphere Melted Zircaloy-2", by I. D. Grozier, L. S. Rubenstein and I. G. Goodwin, ⊜ Preprint No. 148, 1959.

THIS PAPER discusses metallographic observations made to determine the source of elongated defects (referred to as stringers) which occurred in the corrosion oxide of hot worked Zircaloy-2 (1.45% Sn, 0.125% Fe, 0.1% Cr). It had been fabricated from ingots made by melting zirconium sponge in consumable-electrode furnaces under inert atmospheres.

Although fabricated products made from "inert-atmosphere" melted ingots were generally acceptable for reactor use with respect to their corrosion properties, stringers of tan corrosion oxide were occasionally found in the black oxide of hot rolled or extruded material which had been corrosion tested in 750° F., 1500-psi. steam or 680° F. water. The revelation of these occasional stringers caused some concern because it was feared that they might affect cladding integrity. To determine the source of the corrosion stringers, samples were prepared for metallographic examination. Preliminary examination indicated that the corrosion stringers were associated with elongated porous areas in the metal (referred to as microstructural stringers). To substantiate whether the elongated structural defects were "nucleation sites" for the tan corrosion product, samples of hot rolled Zircaloy-2 strip were machined and polished on longitudinal and rolling plane surfaces. Areas containing stringer porosity were marked and the samples subsequently corrosion tested in 1400° F. steam for 14 days. Tan oxide formed over the porosity.

Extended testing in 750° F., 1500-psi. steam showed that the corrosion oxide would be restricted to the locale of the porosity and would not propagate. Thus, cladding integrity would not be affected providing the cladding thickness was greater than 0.0016 in. and the distance from the fuel to the transverse edge of the cladding not less than 0.070 in.

To determine whether ingot porosity or porous regions high in im-

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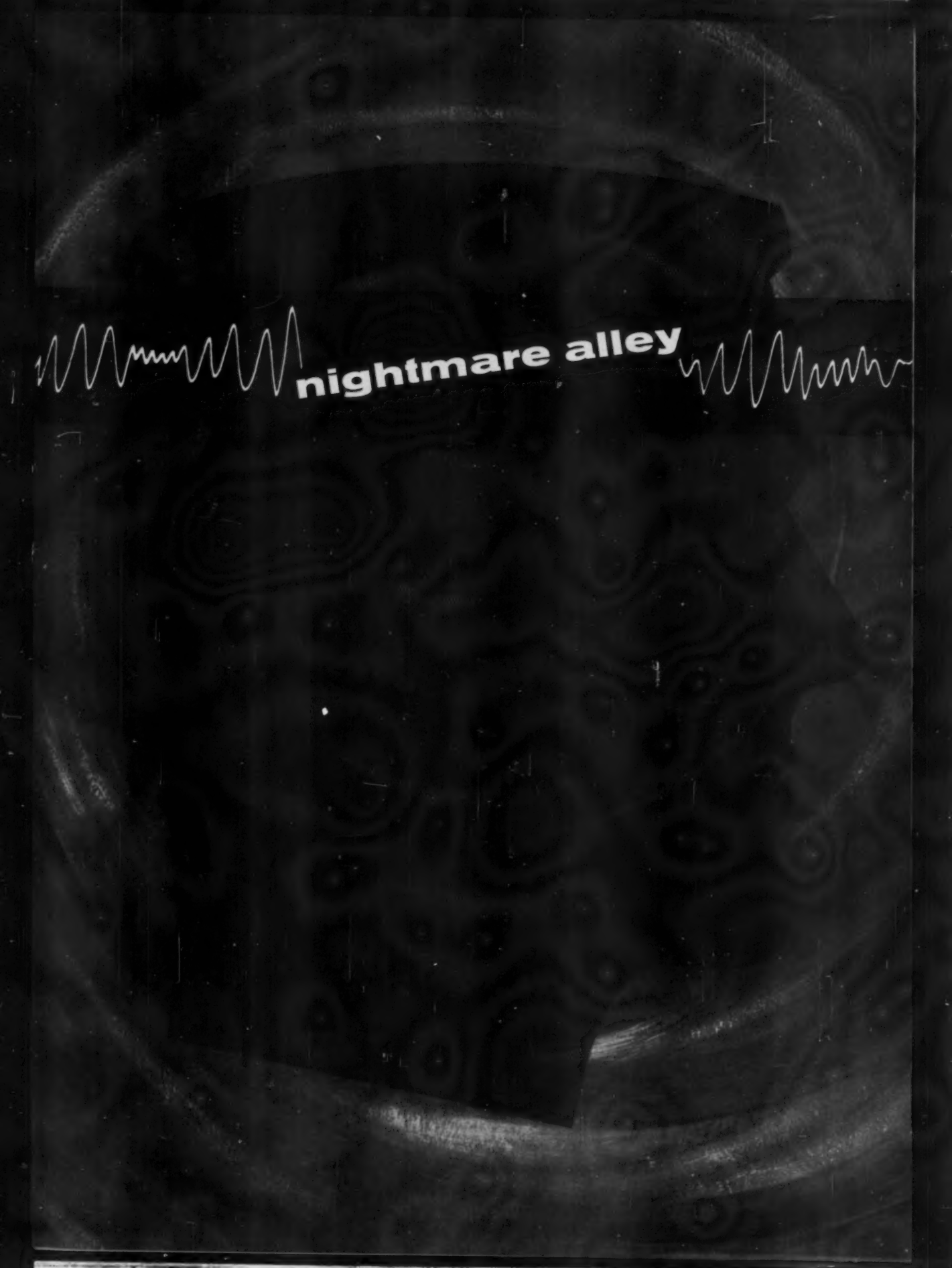
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Zircaloy-2 . . .

purity content could be the source of microstructural stringers, a section of an ingot exhibiting both these conditions was hot rolled at 1550° F. Changes in appearance of the defects were observed as hot reduction proceded. After reduction, the original pores appeared as elongated microstructural stringers. Regions of high impurity content which occurred at the intersection of large dendritic grains were found to be elongated. They appeared as grain-boundary precipitate in the hot rolled strip. Homogenizing at 1850° F. for 4 hr. did not remove microstructural stringers originating from gas voids. The elongated grain-boundary precipitate, however, appeared to dissolve in the beta phase during the heat treatment and was finely redistributed in the alpha grain boundaries during cooling. Thus, microstructural stringers can be attributed to gas voids in the ingot, not porous regions high in impurity content at the intersection of the dendritic ingot grains.

It was further shown that by treating a sample containing microstructural stringers at 1850° F. for 8 hr., corrosion stringers in the oxide coating would not occur. The explanation is given that concentration gradients formed at or adjacent to the stringers during hot working were removed by homogenization. Thus the stringer corrosion oxide is a result of a precipitate on the wall of, or a depleted area adjacent to, a microstructural stringer.

W. R. Opie

Selenium in 5% Cr Steel

Digest of "The Effect of Selenium on the Machinability and Tensile Properties of Five Per Cent Chromium Steel", by F. W. Boulger, ● Preprint No. 131, 1959.

The characteristics of hot work steels ordinarily used for tools and dies are of considerable interest for many current and potential structural applications requiring high strength levels and resistance to tempering at reasonably high temperature. Unfortunately, the relatively high alloy contents of these steels makes them difficult to ma-

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Mr. Juetten's report follows:

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10′ x 2-3/16″ dia. shaft	$28.30	10′ x 1-11/16″ dia. FATIGUE-PROOF	$22.59
3½″ shaft housing	26.30	3″ shaft housing	19.80
2 bearings, 3½″ x 2-3/16″	21.72	2 bearings, 3″ x 1-11/16″	13.46
Shaft coupling	5.16	Shaft coupling	2.34
TOTAL cost	$81.48	TOTAL cost	$58.19
Cost per foot	$ 8.15	Cost per foot reduced to	$ 5.82

RESULT: A saving of $2.33 per foot . . . or $699.00 when applied to a 300-foot pump setting. And this doesn't take into consideration reduced power consumption.

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Chromium Steel . . .

chine. Thus, incentive exists for developing ways to improve the machinability of such materials without lowering the tensile properties.

In this study, the effects of sulphur content up to 0.26% and selenium up to 0.18% in a 5% Cr, 1.2% Mo hot work die steel were investigated by tests on material rolled to 1-in. plates from 100-lb. induction furnace ingots, 4½ in. square. Machinability evaluations and longitudinal and transverse tensile tests were made on annealed (Brinell 190) and hardened (Brinell 330) specimens.

Machinability evaluations were made by a constant-pressure lathe test previously developed for free-machining steels. The tests showed that the first small increments of either selenium or sulphur are most effective for improving machinability. All of the steels, except the base material which contained no added sulphur or selenium, were easier to machine in the hardened than in the annealed condition. In annealed steels, both elements seem to have equivalent effects on a weight basis. In the heat treated (hardened) condition, however, selenium was found to be more effective than sulphur.

The machinability studies also indicate that the benefits of free-machining additives are proportionally larger at the higher strength level. For instance, the machinability ratings indicate that the presence of 0.05% Se would permit an increase in cutting speed, compared to the speed for the untreated material, by 8% at a hardness level of Brinell 190, by 60% at Brinell 330.

The tensile data show that the presence of free-machining additives in amounts up to 0.26% had no significant effect on the tensile strength or ductility of the annealed experimental steels. Nor did the sulphur and selenium contents influence the ratio of the mechanical properties for longitudinal to transverse specimens.

In the heat treated condition (about 280,000 psi. tensile strength), the presence of unusually large amounts of sulphur and selenium did not affect the tensile strengths or the ductility of specimens taken parallel with the direction of rolling. However, the steels containing 0.26% S or 0.12% S plus 0.10% Se had relatively poor ductility when tested in a transverse direction. Obviously, the effect of nonmetallic inclusion content in lowering transverse ductility is much more pronounced in hardened than in annealed specimens. Nevertheless, the test data show that neither sulphur contents up to 0.13% nor selenium contents up to 0.18% have an adverse effect on transverse ductility.

From the results of this investigation, the author concludes that, on a weight basis, selenium is more effective than sulphur in improving the machinability of hot work die steels. The presence of as little as 0.05% Se improved the machinability ratings of bars heat treated to Brinell 330 by more than 50%. The results also show that selenium contents up to 0.18% do not adversely affect the transverse ductility at this strength level. There seems little doubt that improvements of the order noted in these experiments would be of considerable importance in commercial machining operations.

G. H. ENZIAN

Reclaiming Worn Parts

Digest of "Metallizing and Its Application in Aircraft Gas-Turbine Components", by Donald E. Hacker, *Welding Journal*, Vol. 37, March 1958, p. 231-236.

THE PRACTICE of rebuilding metal parts which have been worn or overmachined has been known for some 30 years. For a rebuilding of a few thousandths of an inch, electroplating with nickel or chromium is used. The deposited metal is relatively hard and can be ground to print dimensions. If a greater thickness is required, this process is very slow and the resulting surfaces are not as uniform.

The requirement can be met by a metallizing process invented in principle by M. U. Schoop of Zurich in 1912. Wire or metal powder contained in a "gun" is fed continuously into a high-temperature gas flame. The molten metal is received into a high-pressure stream of air and sprayed onto the metal surface being treated. Any metal or alloy which can be melted may be used. The metal is unexpectedly cold, and can be deposited on paper without any burning effect; nevertheless, the particles adhere firmly to each other, and after machining present a uniform surface. The microstructure reveals a layer effect, not unlike a weld, and chemical analysis shows that oxide particles contaminate the metal and doubtless contribute to the high order of hardness. Mild steel Rockwell C-30 is an example, and Hacker quotes Rockwell C-60 for molybdenum.

By 1948 the practice, says Ballard, was firmly established in America. Hacker explores the extension of the practice to parts where a material is required with high-temperature properties.

He selects molybdenum, and recounts experiences in the treatment of parts for gas turbines. Since the surface to be treated must be very clean, chemical solvents are not good enough. Grit blasting is recommended but details are not given. The surface must be warmed to free it from moisture; surfaces which have absorbed oil will exhude it after cleaning and prevent adhesion of the sprayed metal. He does not mention that the distance between the work and the gun is important and affects porosity. Molybdenum is generally recommended except for parts subjected to high temperatures. The metal is hard, has good bonding quality, and shrinkage is low – a very attractive property. A chemical protective coating is necessary but particulars are not given. An example is shown of an engine component which had operated at 900°F. at speeds of mach 2. It was repaired by building up with 0.040-in. molybdenum, and covering with 0.1% carbon steel. An overmachined gear was rebuilt with 0.015-in. stainless steel. An interesting example is the use of a silver alloy to provide an extremely close running tolerance and so prevent seizure and minimum air leakage.

The paper should encourage engineers, who have not done so, to explore the economies of this method of reclamation and those who have found limitations in their work to try molybdenum, but perhaps in consultation with Hacker.

JOSIAH JONES

Impact Extrusion of Aluminum Alloys

Digest of "Latest Developments in Impact Extruded Aluminum Alloys", by R. A. Quadt, S.A.E. Preprint 65 D. Paper presented at the summer meeting of the Society of Automotive Engineers, Atlantic City, N.J., June, 1958.

TUBES UP TO 20 in. diameter can be formed by impact extrusion. Only trimming, drilling and slotting are needed to complete the motor tube for a Sidewinder guided missile. A 6063 aluminum tube has been cold extruded to 45 ft. in length (with nonsymmetrical cross section and basic wall thickness within 0.003 to 0.006 in.), and a one-piece heat treated impact replaced a six-piece welded assembly of lower strength and unacceptable tolerances.

The most complicated impact extrusion assembly to date is described. Made of aluminum alloy 2014-T 6 (length 100 in., wall 0.050 in.), one end is closed with internal and external bosses and there are ribs (one external and three internal) of different sizes running the whole length.

A particular achievement is a forged piston with 64,000 psi. tensile strength, 54,000 psi. yield strength, 8% elongation and a hardness of Brinell 110 to 120 which showed no change in dimension after 50 hr. of treatment in a V-8 engine run intermittently at various power settings while under abnormal testing conditions.

No details are given of design of slugs and dies or essential lubricants. The author is content to admit that improved extrusion blanks, doubtless from ingots cast continuously, have helped and that new lubricants, rigid tooling and fast acting presses have done the rest.

The established process of completing the formation of powder metallurgy compacts by extrusion has been brought up to date by the production of a tube of sintered aluminum powder (SAP) with the following properties after annealing: 51,200 psi. tensile strength, 43,000 psi. yield strength, 10% elongation and a hardness of Brinell 83.

The impact extrusion method of producing collapsible toothpaste tubes and similar unstressed shapes in very soft aluminum has long delighted the production engineer, but R. A. Quadt now says in no uncertain terms that large and complex parts are available in high-tensile alloys with improved properties and tolerances. There would seem to be no good reason why the process can not be extended to other and stronger alloys.

JOSIAH JONES

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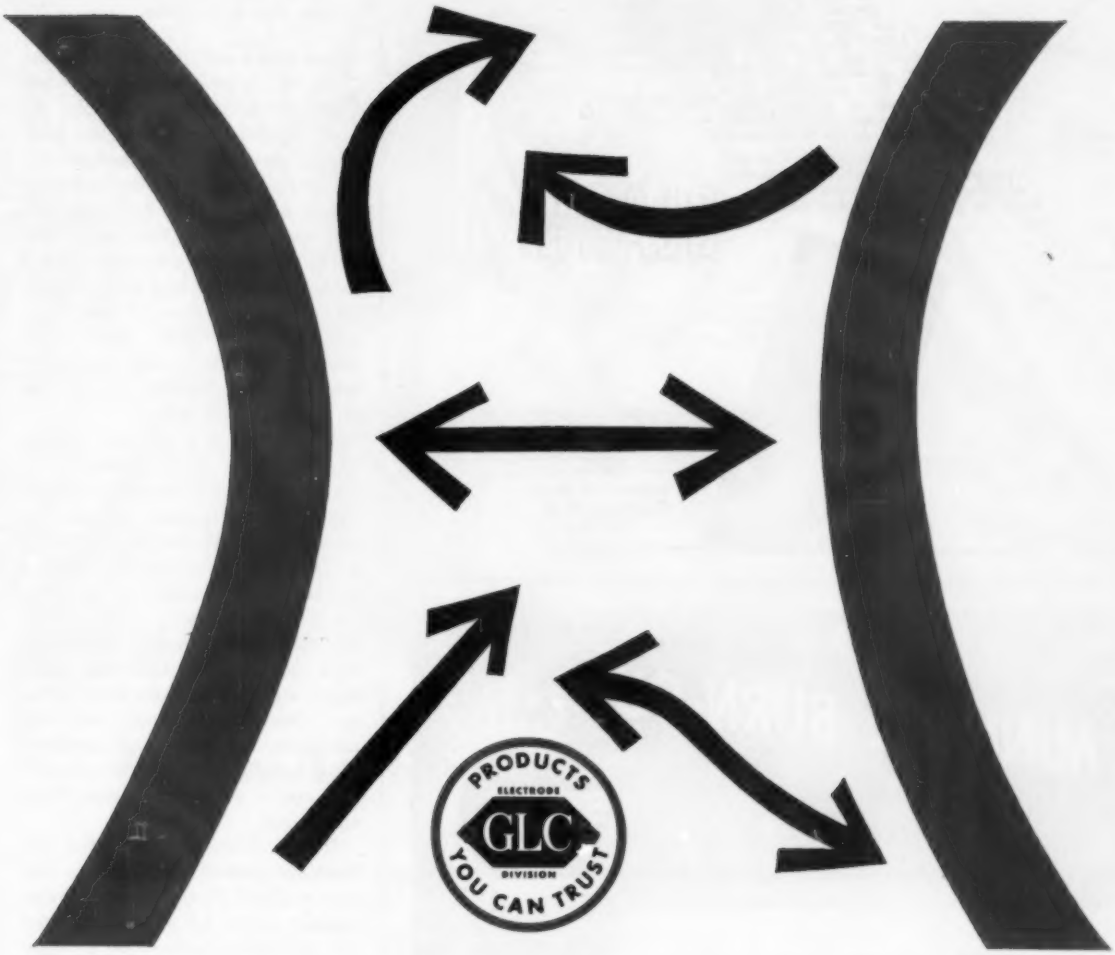

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Brazing and Braze Welding of Beryllium

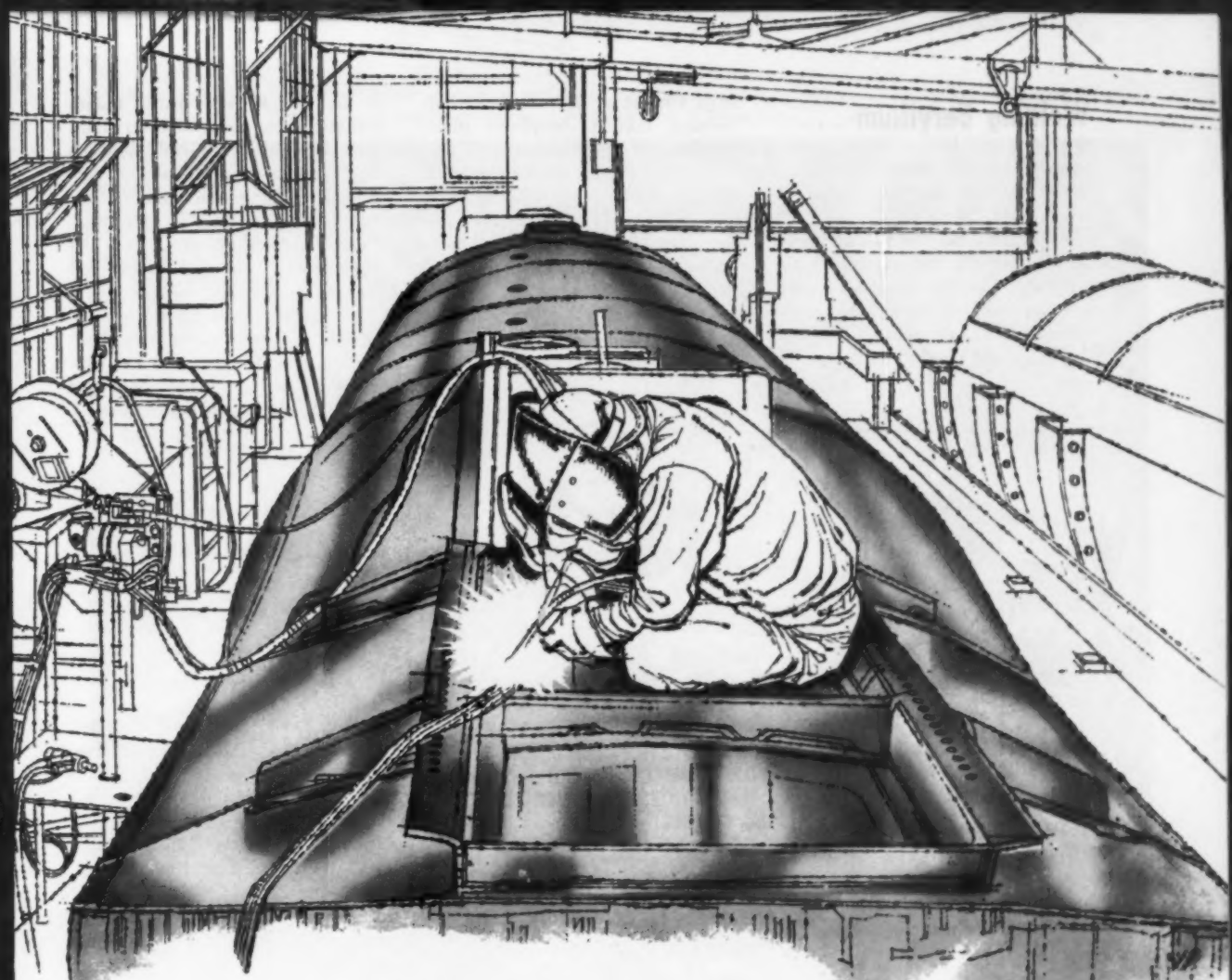
Digest of "Joining of Beryllium", by N. E. Weare and R. E. Monroe, Defense Metals Information Center Memorandum No. 13, Battelle Memorial Institute, March 30, 1959.

THIS SUMMARY of the information in 16 documents, all published since 1952, indicates vividly the rapid advance in metallurgical techniques generally. The authors evidently feel that all relevant information is no more than five years old, and mention more than once their belief that current investigations will revise even such recent data. Nearly all of their references are from three sources – the A.S.M. book "The Metal Beryllium", and documents originating at Battelle and at the U. S. Bureau of Mines.

Fusion welding by any process seems to have been inadequate so far for joining commercial beryllium, which is very coarse grained, hot short and almost completely lacking in ductility. The thermal stresses are sufficient to crack the metal in the joint or alongside. The authors say that electron-beam welding in high vacuum and tungsten-arc welding in argon atmosphere show promise. Oxide forms readily and contaminates the joint; and available "flux" is heavier than molten beryllium, and it sinks rather than floats and fluxes!

If two chemically clean, flat surfaces are pressed together in a vacuum at 2200° F., the abutting grains coalesce within 2.5 hr., and the joint has properties comparable to commercial beryllium treated at the same temperature. Such "solid-state welding" is adaptable only to the simplest shapes.

Furnace brazing in vacuum, dry hydrogen or inert gas has successfully joined beryllium to itself and to other metals. Recommended brazing foils are silver and the 72-28 Ag-Cu eutectic. Temperature must be limited to that required to melt the braze (about 1500° F.); time must be short (1 or 2 min.) else the molten braze spreads out and leaves voids in the joint. Mild pressure also helps. Step joints scarf joints, or butt joints are desirable; others put damaging bending



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Welding Beryllium . . .

stresses into the assembly. Scarf brazes in beryllium have a shear strength of 5500 psi.

Apparently the best joining method is what the authors call "braze welding", namely, consumable arc welding using an 88-12 Al-Si alloy electrode, 1/16-in. diameter, helium shielding and welding with a 175-amp. current at 28 volts. In butt welding 0.25-in. beryllium plate, the joint is scarfed to a 40° Vee, 0.12-in. root gap, and mounted 0.12 in. above a copper back-up strip. The first pass at 6 in. per min. fills the joint; it is then turned over, the root cleaned and filled by a second pass at 32 in. per min. Thicker plates require third or fourth passes to fill the top part of the Vee. There must be no undercutting or notches at the surface, else brittle failure will start from stress concentrations. The parts being welded must be free to move – no restraint is permissible. Butt welds made in this way in 0.25-in. beryllium plate have ultimate strengths of 23,000 to 31,000 psi. (The original unwelded plate tests 32,000.)

All manual welding or brazing should be done in glove boxes, and furnace atmospheres carefully ventilated to make sure that toxic volatile compounds are not inhaled.

E.E.T.

Corrosion by Liquid Bismuth

Digest of "The Corrosion of 2¼% Cr-1% Mo Steel by Liquid Bismuth", by G. W. Horsley and J. T. Maskrey, *Journal*, Iron and Steel Institute, June 1958, p. 139-148.

WORK AT Brookhaven National Laboratory has indicated that steels with low chromium (2 to 5%) and molybdenum (1%) are relatively resistant to corrosion by liquid bismuth. Even such alloys, however, when used in thermal convection loops with maximum temperatures up to 1150° F., temperature gradients up to 300° F., and fluid velocities of about 0.15 in. per sec., have corrosion rates of 0.65 in. per year or greater.

Small amounts of zirconium (250 ppm. or more) inhibit corrosion and can reduce the mass transfer rate by a factor of ten. The effective corrosion rate, however, is only reduced by a factor of four by initial addition of 250 ppm. zirconium, since localized pitting develops. Maintaining zirconium content at about 250 ppm. does not eliminate pitting until the nitrogen content of the steel is increased to about 1%. This decreases the corrosion rate to about 0.010 in. per year and possibly to 0.001 in. per year.

Zirconium apparently decreases corrosion of steel by liquid bismuth through the formation of a surface layer of zirconium compounds, principally nitride, which prevents solution of the steel in bismuth. With initial zirconium addition only, protection is temporary since the surface layer is likely to spall off; it does not re-form. Increased nitrogen

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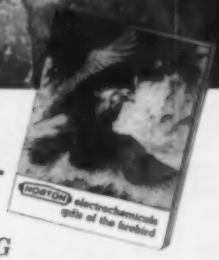

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Corrosion . . .

content in the steel apparently produces a more protective zirconium nitride film containing fewer distorting impurities than the film formed on unnitrided steel. Moreover, this additional nitrogen content may also repair the film when it is disrupted.

The effects of reactor radiation have not been firmly established. All that can be said is that there are no beneficial effects. However, corrosion resistance and efficiency of inhibition may be reduced.

C. O. SMITH

Irradiation of Copper and Nickel

Digest of "The Effect of Neutron Irradiation on the Mechanical Properties of Copper and Nickel", by M. J. Makin, *Journal*, Institute of Metals, Vol. 86, June 1958, p. 449-455.

COPPER AND NICKEL of commercial purity were irradiated for six months at about 100° C. (212° F.) in a thermal flux of 6×10^{12} slow neutrons per sq. cm. per sec. The ratio of fast flux to thermal flux is estimated to be about unity. The effects of this irradiation on tensile properties at temperatures from −195 to +200° C. (−320 to +390° F.) were investigated.

The appreciable alteration of stress-strain characteristics by irradiation is similar for copper and nickel. Both yield and tensile strengths are increased over the temperature range with a much greater increase in yield than in tensile strength. Yield stress of unirradiated metal is only slightly temperature dependent whereas the higher yield stress of irradiated metal is strongly temperature dependent with the increase being much greater at low than at high temperatures. The temperature dependence is a reversible phenomenon and not a thermal annealing effect.

Irradiation develops a yield point phenomenon, similar to that observed in austenitic stainless steels, in contrast to no observable yield point in unirradiated metal.

The rate of work hardening at small extensions is drastically reduced and elongation before fracture is appreciably less than in unirradiated metal.

The effect of irradiation on tensile properties of copper and nickel is quite similar to the effect of adding a solid-solution alloying element. A major difference is in rate of work hardening at small strains. An analogy between irradiation effects and cold working is very poor.

It is postulated, because of the large effects of irradiation on stress-strain characteristics and the constancy of yield characteristics over the wide temperature range, that hardening is due either to formation of jogs on dislocations by condensation of point defects or to the small planar clusters of interstitial atoms or vacancies.

C. O. SMITH

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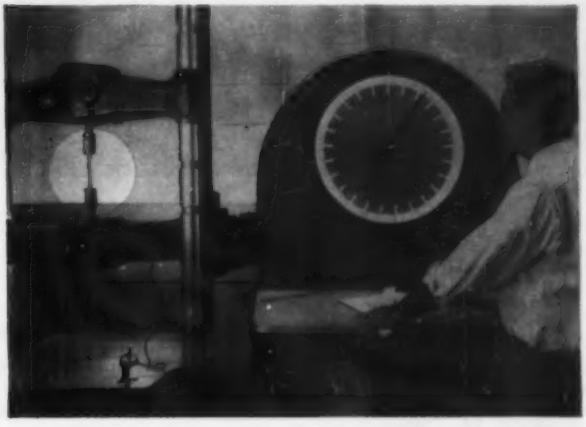
Robert Timko, Metallurgist

"At Jessop, tensile testing of specialty steels is carried out with far more than ordinary precision. It pays. It's one of the reasons our repeat business is so high.

"Based on a series of photographs, this drawing shows a specimen of type 304 annealed stainless steel bar at the climax of a tensile strength test. Moving apart, the heads of the tensile testing machine stretched the bar until it finally ruptured at 5500 psi above the spec."

In this Jessop metallurgical laboratory, top metallurgists using all types of modern testing equipment help us make certain you get *consistent* high quality in specialty steels. *Specify Jessop . . . and then relax.*

VMA 6788



Tensile testing machine in the Jessop metallurgical lab. Stretch, strain and then bang! The specimen of type 304 annealed stainless bar ruptured at 5500 psi above the spec. Tensile strength okay!

In the Jessop metallurgical lab, this tensile testing machine is one of many types of tools used to make certain you get *exactly* what you want in specialty steels.

Jessop Steel International Corporation
Steel Warehousing Corporation, Chicago
Green River Steel Corporation
Jessop Steel of Canada, Ltd.

JESSOP
STEEL COMPANY
Washington, Pennsylvania

Stainless, alloy, cast-to-shape, clad and forging steels, ground flat stock and other specialty steels

Superex is easily combined with other insulations such as Johns-Manville Thermobestos®, J-M 85% Magnesia or J-M Insulating Fire Brick.

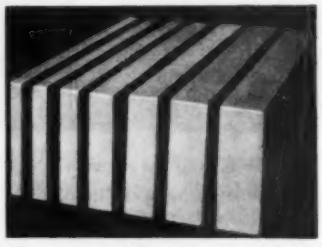
Only Johns-Manville Superex insulation performs 3 ways better at high temperature!

Few industrial products are so outstandingly superior, or so widely used in their area of application, as Johns-Manville Superex® Insulation.

A block insulation formulated of diatomaceous silica and asbestos for furnace and other applications, Johns-Manville Superex brings many advantages to high-temperature service—each contributing to reduced construction, maintenance and operating costs.

Superex is installed with measurable savings in time and labor! It is easy to cut and handle . . . weighs only 2 lbs. per sq. ft. per inch thickness . . . available in a wide variety of large block shapes and sizes. At high temperature—the material's excellent insulating value, thermal stability and resistance to shrinkage keep fuel costs low. Equally important—Superex saves on maintenance, too . . . . easily withstands the daily abuse of normal service.

Send for your copy of IN-190A, the 12-page design and technical data brochure. It lists suggested applications—gives complete heat transmission tables and performance data. *Write for it today.* Address Johns-Manville, Box 14, N.Y. 16, N.Y. In Canada, Port Credit, Ont.



Saves waste. Superex comes in 7 standard thicknesses from 1″ to 4″. Other sizes available on order.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

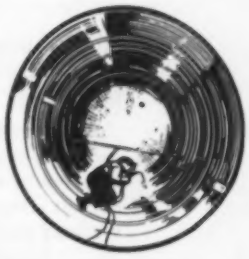
"ELECTROMET columbium alloys suit our needs best"

Columbium can be efficiently added to carbon and alloy steels and high-temperature alloys with ELECTROMET ferrocolumbium or ferrotantalum-columbium. Electric furnace and open-hearth operators can use these alloys to produce:

- Carbon and low-alloy steels, where columbium promotes a fine-grain structure for improved strength and weldability.
- Iron-, nickel-, and cobalt-base high-temperature alloys, where columbium improves strength at elevated temperatures.
- Stabilized austenitic stainless steels, where columbium inhibits intergranular corrosion.
- Non-air-hardening plain-chromium steels, where columbium minimizes air-hardening and acts as a grain refiner.

Ask your UNION CARBIDE METALS representative for further details.

UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.



Welding Cb-stabilized stainless.
For information on columbium uses, contact UNION CARBIDE METALS, pioneer in columbium development.

UNION CARBIDE METALS

***Electromet** Brand Ferroalloys and other Metallurgical Products*

Radiographs-

dry and ready-to-read in 13 minutes

KODAK INDUSTRIAL X-OMAT PROCESSOR

Now it takes only 13 minutes to process your industrial radiographs. The Kodak X-Omat Processor produces radiographs of uniform high quality . . . and it brings automation to your darkroom.

Exposed films are merely removed from their holders and fed directly into the processor. Film hangers are eliminated. And only 22 inches of the unit's 10-foot, 10-inch length need extend into the darkroom itself.

Kodak Industrial X-ray Films, Type AA and Type M—sheet films or continuous lengths—go through the system at the rate of 38 inches per minute.

This means time saved and costs cut. You should have the complete story. Send for the folder that gives all the details.

X-ray Division — EASTMAN KODAK COMPANY — Rochester 4, N.Y.

EASTMAN KODAK COMPANY, X-ray Division, Rochester 4, N. Y. 55-11

☐ Send the folder about the Kodak Industrial X-Omat Processor.

☐ Send the names of the Kodak Industrial X-Omat Processor dealers in my area.

Name _____

Firm Name _____

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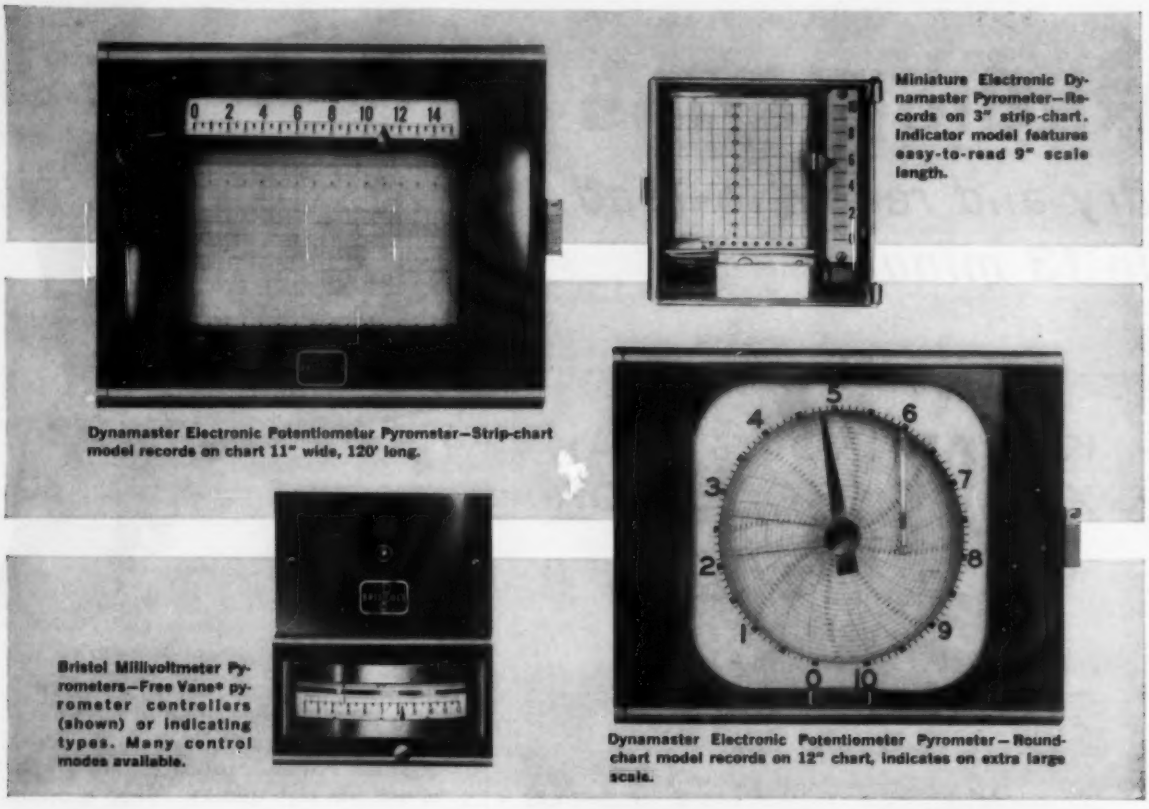
Kodak



Dynamaster Electronic Potentiometer Pyrometer—Strip-chart model records on chart 11" wide, 120' long.

Miniature Electronic Dynamaster Pyrometer—Records on 3" strip-chart. Indicator model features easy-to-read 9" scale length.

Bristol Millivoltmeter Pyrometers—Free Vane* pyrometer controllers (shown) or indicating types. Many control modes available.

Dynamaster Electronic Potentiometer Pyrometer—Round-chart model records on 12" chart, indicates on extra large scale.

MODERN PYROMETERS...key to profitable use of HEAT

Bristol recording and automatic controlling pyrometers for temperatures up to 5000°F can help you increase product uniformity, cut fuel and maintenance costs

Bristol makes a wide range of pyrometers for every requirement: Electronic potentiometers, millivoltmeter and radiation types . . . for furnaces, ovens . . . every type of heating equipment, every kind of fuel. The reliability and accuracy of these precision instruments have been proved in thousands of installations.

Take just one advanced Bristol instrument, for example, the Electronic Dynamaster* Potentiometer Pyrometer:

CONTINUOUS STANDARDIZATION PLUS ACCURACY OF STANDARD CELL

Continuous standardization in Dynamaster Electronic Pyrometers requires no dry-cells, **but still retains the precision standard cell for highest stability and accuracy of voltage reference.** Results: No interruption to operation, no batteries to change. And here are just a few of the Dynamaster types available:

A model for every requirement: Dynamaster Pyrometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

Electric and pneumatic controllers: Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control—on-off, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control—on-off, proportional, and proportional with reset.

Miniature Dynamaster Pyrometer: Full plug-in flexibility . . . takes only 5" x 5⅛" of panel space, but has same basic accuracy, same time-tested operating principle as full-size Dynamaster pyrometers described above. Ideal for graphic panels and centralized recording or indicating of large numbers of variables. Either electrical or pneumatic control types available.

Write for complete data on Bristol Pyrometers—and remember Bristol offers a complete line of thermocouples and pyrometer accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

*T.M. Reg. U.S. Pat. Off.

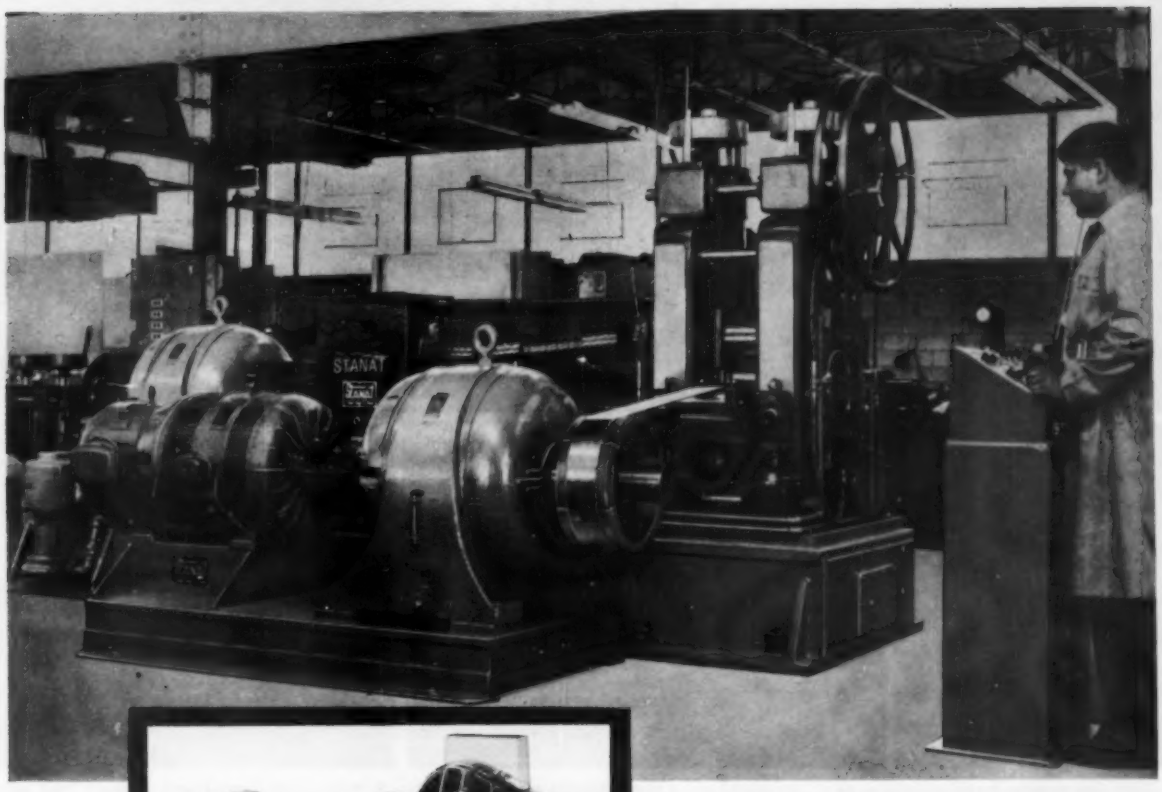
BRISTOL... for improved production through measurement and control

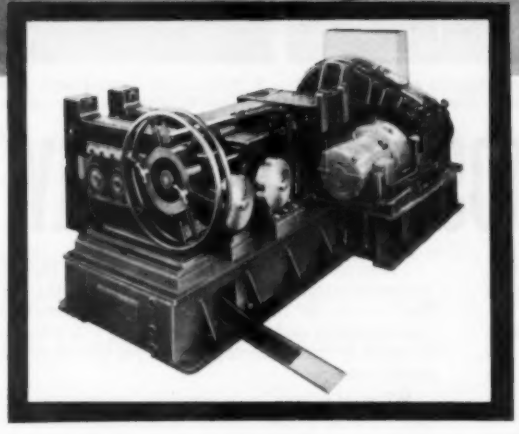
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

All Purpose

STRIP MILLS *Adaptable to...*

METAL POWDER ROLLING





PRECISE, RUGGED, VERSATILE

Highest quality is engineered into each minute detail of every STANAT mill. Long dependable performance in over 500 installations throughout the world attests to the extremely rugged, high precision construction of STANAT rolling mill equipment.

Whatever your present or future requirements, you can now have a single STANAT MILL for any or all of the following...

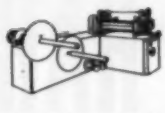
- Rolling Metal Powders into strip
- 2-high hot or cold reducing
- 4-high finishing
- Back-up or work-roll driven operation
- Hot or cold shape rolling
- Tension winding to ultra thin gauges
- Automatic roll changing (for glove-box operations)

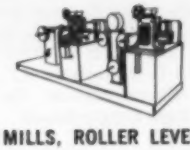
Write for full details.

STANAT / MANUFACTURING CO., INC.

500 SHAMES DRIVE WESTBURY, L. I., N.Y.

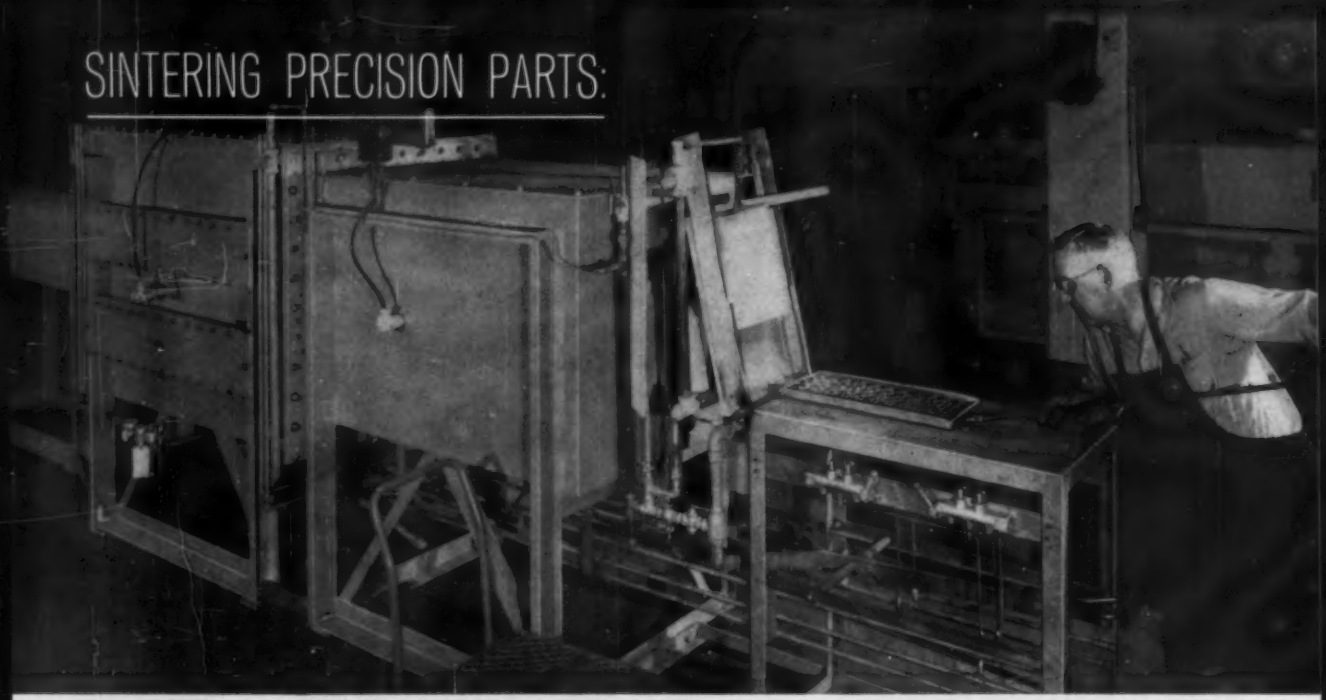
IN EUROPE: STANAT-MANN, ESSEX, ENGLAND





MFR'S OF ROLLING MILLS, GANG SLITTERS, WIRE FLATTENING MILLS, ROLLER LEVELERS AND BULL BLOCKS

SINTERING PRECISION PARTS:



1. Green compacts are closely grouped on perforated steel trays for maximum productivity.

2. Loaded tray is pushed through gas flame curtain of open charging door into pre-heat chamber.

3. Trayload of sintered parts is drawn from cooling chamber through gas flame curtain of discharge door.

TEMPERATURES, ATMOSPHERES TIGHTLY HELD

Serving a large Eastern metal fabricator, this Harper Box Furnace sinters a variety of precision parts compacted from iron, iron graphite, 4600 series steel and brass powders. As the compacts move through the furnace's pre-heat, high temperature and cooling chambers, both temperature and atmosphere are controlled to insure precision work in numerous ways:

In the pre-heat (or burn-off) chamber, nickel-chromium elements provide temperatures up to 1500° F. An Inconel muffle retains protective atmosphere and prevents volatiles from collecting on the heating elements to cause short circuiting, muffling, grounding or chemical corrosion. Volatiles burned off at the top outlet are discharged through a vent pipe, while carbon and zinc oxide ash are readily brushed from the muffle.

After being pushed into the high temperature chamber, the parts can be processed at temperatures up to 2400° F. With the chamber's pneumatically-operated refractory doors acting as radiation screens, silicon carbide heating elements are arranged above and below the work to maintain the temperature desired within ±5° F throughout 32" of the 36" chamber length. Made of silicon carbide, the hearth plate retains its flatness under high temperatures.

From the high temperature chamber, the parts enter the water-jacketed cooling chamber. Automatic control of water flow assists in regulating work temperature and prevents condensation within the liner during idle periods. From start to finish in this sintering operation, *Harper furnace features insure success.*

When it comes to a sintering or brazing furnace of any type — box, pusher, mesh belt, roller hearth, bell, elevator or pit — you'll find it pays to put it up to Harper — for Harper has the experience to both recommend and build the furnace that's best suited to your needs (with either gas or electricity or both as the source of heat). For more information, write: Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

HARPER ELECTRIC AND GAS FURNACES

FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH

No. 1 and No. 2 Hot-Dip Galvanizing Lines, Martins Ferry Plant, Wheeling Steel Corporation

Wean, Wheeling and Galvanizing . . .

The advantages of corrosion-resistant, zinc-coated sheets might well have been lost to history had it not been for the development of continuous, hot-dip galvanizing lines. Such lines brought galvanized sheets within the rigid limitations of acceptable product and did so at much lower operating costs.

The Wean Engineering Company worked in close cooperation with the Wheeling Steel research department on the development, design, and construction of these lines at the Martins Ferry plant. The lines are currently producing a wide range of top quality galvanized sheets and coils at speeds up to 300 fpm.

Wean has designed and built galvanizing lines for a wide variety of customer requirements. Why not take advantage of Wean's *creative engineering* experience on your next coating line project.

THE WEAN ENGINEERING COMPANY, INC. • WARREN • OHIO

X-ite

THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION

NATIONAL ENGINEERING SERVICE *on*

Heat and Corrosion Resistant Castings and Fabrications

General Alloys Company products are backed by a national engineering service offering unexcelled mechanical and metallurgical Heat and Corrosion Resistant Alloys for all Defense and Industrial applications.

"There is no substitute for Experience"

GENERAL ALLOYS BRANCH OFFICES AND REPRESENTATIVES

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Cross Sales & Engineering Co.
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BALTIMORE, Maryland
Emil Gathmann, Jr.
413 North Charles Street

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General Alloys Company
Robert M. Robinson
P.O. Box 2288
Buffalo 28, N.Y.

BIRMINGHAM, Alabama
Harry G. Mouat Co.
844 American Life Bldg.

CHICAGO, Illinois
General Alloys Company
Edward T. Connolly
224 S. Michigan Ave.

CLEVELAND 15, Ohio
E. E. Whitnight
Room 305, Plymouth Bldg.
2035 East 22nd Street

DENVER 15, Colorado
Tracy C. Jarrett
66 S. Ammons St.
P.O. Box 7897

PHILADELPHIA 28, Pa.
General Alloys Co.
Bernard J. Conway
P.O. Box 2714

DETROIT 2, Michigan
General Alloys Company
Don B. Hutchins
3-147 General Motors Bldg.

FORT WAYNE 8, Indiana
The George O. Desautels Co.
P.O. Box 1178
2906 Broadway

HOUSTON 3, Texas
Wm. E. Brice Co.
303 Bastrop St.

PITTSBURGH 15, Pa.
Vincent C. Leatherby
104 Fourth St.
Sharpsburg, Pa.

ROCKFORD, Illinois
Benjamin F. Ottman
1803 Jonathan Ave.

LOS ANGELES, Calif.
National Furnace
Sales & Service, Inc.
5251 Tweedy Blvd.
South Gate, California

LOUISVILLE 7, Kentucky
The George O. Desautels Co.
4003 Hycliffe Avenue

INDIANAPOLIS 8, Indiana
The George O. Desautels Co.
2302 N. Meridian Street
P.O. Box 88008

ST. LOUIS 16, Missouri
Associated Steel Mills, Inc.
P.O. Box 1206
Meramec Station

MEMPHIS 12, Tenn.
F. G. Desefrio
463 Scott St.

MUNCIE, Indiana
The George O. Desautels Co.
P.O. Box 778
405 Wyser Bldg.

NEW ENGLAND
David L. Ellis
Hayward Mill Road
West Concord, Mass.

NEW YORK 7, New York
General Alloys Co.
Alfred M. Sampter
50 Church Street

GENERAL ALLOYS

GENERAL ALLOYS CO.

405 WEST FIRST STREET BOSTON, MASS.

"OLDEST AND LARGEST EXCLUSIVE MFRS. OF HEAT & CORROSION RESISTANT CASTINGS"

"Dad believes in good guns and good gun manners"

"He just bought me a new gas-powered Hahn BB rifle. It's real sharp and shoots straight, but he won't let me use it alone until I've learned good gun manners."

Hahn BB guns, styled after famous lever-action Western frontier rifles, have the look and feel of Dad's guns—and they shoot straight. This is due to the accuracy of the barrels. They are made from commercial grade Superior carbon steel tubing —known for the consistent uniformity of its ID finish, free machining characteristics and economy.

Examples of other unusual applications of this Superior tubing

- Carbon steel rectangular tubing for collimating tubes in a research reactor (.900 in. x .400 in. ID x .025 in. wall in 10-ft. cuts)
- Specially conditioned ID tubing in long lengths used as high pressure diesel lines on earthmoving equipment (¼ in. OD x .088 in. ID)
- Cadmium plated compression sleeves for connecting the steel core of ACSR high tension cable (.404 in. OD x .179 in. ID in 5-in. cuts)
- 2½ million ft. of carbon steel tubing in random lengths for the gear pinion in the timing fuse of artillery shells (.204 in. OD x .067 in. ID)

Filling tubing orders that range from a few feet to millions, in a wide variety of materials, shapes and sizes, calls for the resources Superior has to offer. Why not investigate the advantages of using us as a source of tubing. Bulletin 41, a guide to the selection and application of Superior tubing, is yours for the asking. Write Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

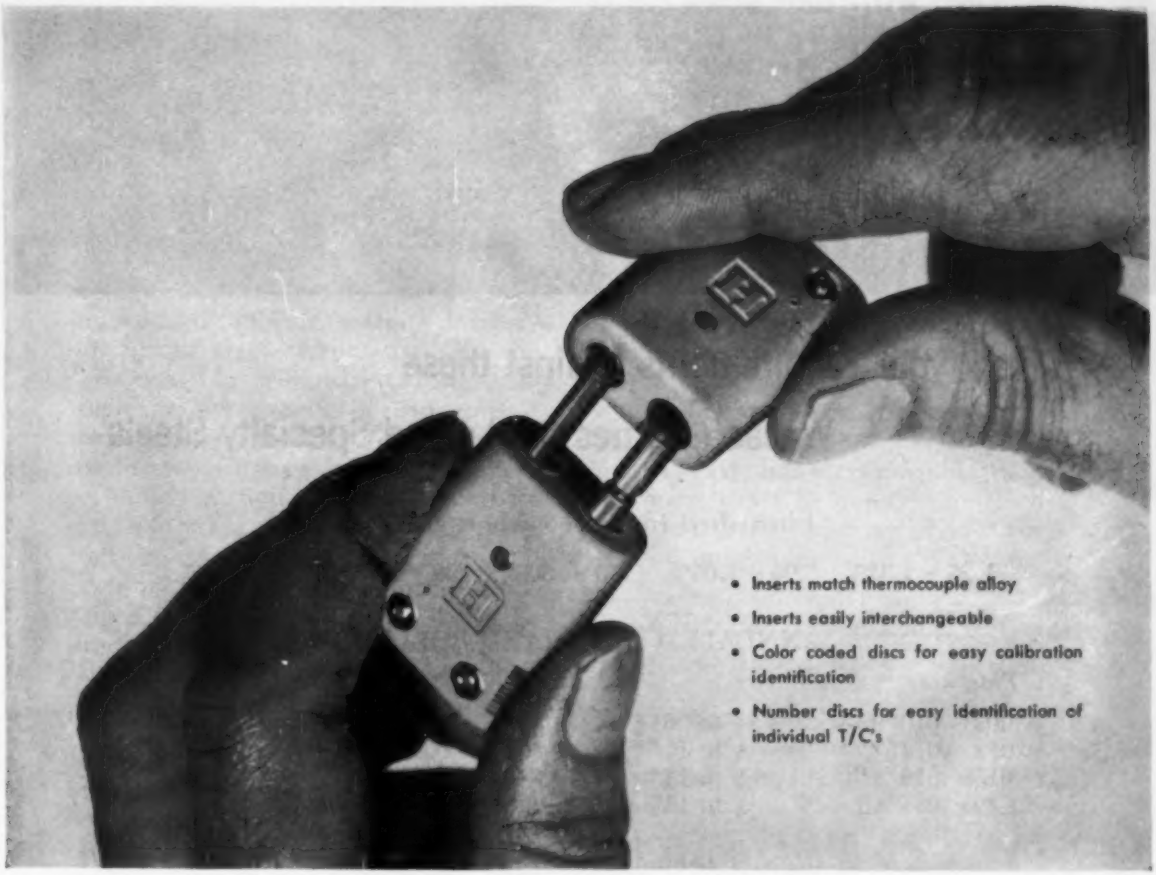
Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331



NEW *QuiK-Konnect** thermocouple components

For accurate, swift, and foolproof connection of thermocouples to extension wire

New *QuiK-Konnect* plug and jack bodies give fast, easy, and foolproof extension wire connections in plant, laboratory or test cell installations.

Inserts have different diameter positive and negative poles, for foolproof connection . . . are extremely easy to remove for field calibration change or replacement. Various tube adapters are available to protect small-diameter thermocouples, and cable clamps can be supplied to protect extension wires from fraying or tearing.

The *QuiK-Konnect* line, in addition to plugs and jacks, includes:

1. Single-jack panel that fits ¾-in. knockout.
2. 4-point jack panel that fits standard electrical outlet box.
3. Multiple jack strips.
4. Custom-built multiple jack panels.
5. *QuiK-Kords** for patch programming multiple jack panels.

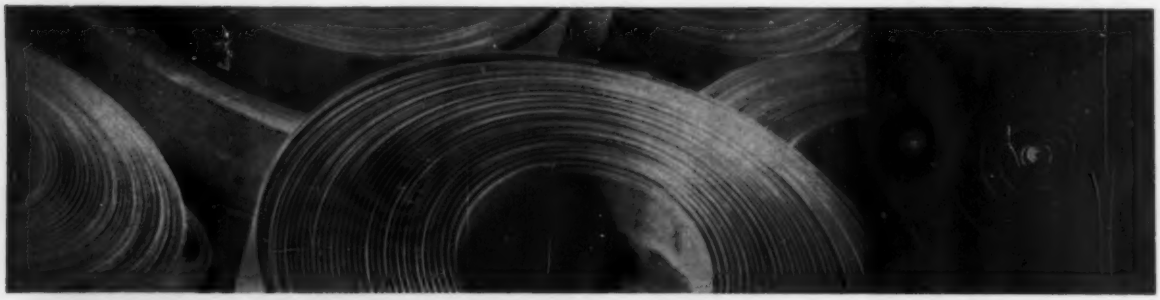
You can get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, 21 Penn St., Fall River, Mass.

*Trademarks

Honeywell

H HONEYWELL First in Control



Check your requirements against these

Wallace Barnes Cold-rolled Specialty Steels

Furnished in these carbon grades:

1.25 – 1.32% .90 – 1.05% .70 – .80% .59 – .74% .48 – .55%

ANNEALED AND HARD-ROLLED

Thickness

.003 – .010″	in widths	1/8 to 6 1/4″	
.011 – .014″	" "	3/16 to 11″	
.015 – .019″	" "	3/16 to 13″	
.020 – .035″	" "	1/4 to 13″	
.036 – .049″	in widths	3/8 to 13″	
.050 – .064″	" "	1/2 to 13″	
.065 – .093″	" "	3/4 to 6 1/4″	
.093 – .125″	" "	3/4 to 6 1/4″	

HARDENED AND TEMPERED

Scale-free or scaleless; polished*; polished and blued*; polished and strawed*

Thickness

.003 – .004″	in widths	1/8 to 2″	
.005 – .007″	" "	1/8 to 3″	
.008 – .009″	" "	1/8 to 4″	
.010 – .014″	" "	3/16 to 5″	
.015 – .019″	" "	3/16 to 7″	
.020 – .025″	" "	1/4 to 8 1/2″	
.026 – .030″	" "	1/4 to 8″	
.031 – .035″	in widths	1/4 to 7″	
.036 – .040″	" "	3/8 to 7″	
.041 – .049″	" "	3/8 to 6″	
.050 – .060″	" "	1/2 to 4″	
.061 – .064″	" "	1/2 to 3″	
.065 – .093″	" "	3/4 to 3″	

*Maximum width for polishing in .010 – .030 thickness ranges is 5 in.

Facilities for processing alloy steels also are available.

Standard sizes normally available for prompt shipments.

Write for a copy of "Physical Property Charts" that give performance characteristics of .90 – 1.05% and .70 – .80% carbon grades.

Wallace Barnes Steel Division

Bristol, Connecticut

Associated Spring Corporation

III

KNOW YOUR ALLOY STEELS . . .

This is the third of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

What Does Grain Size Mean In An Alloy Steel?

The grain size of alloy steels is generally understood to mean austenite or inherent grain size, as indicated by the McQuaid-Ehn carburizing test. Austenite grain size should be distinguished from ferrite grain size, which is the size of the grains in the as-rolled or as-forged condition with the exception of those steels that are austenitic at room temperature. When steel is heated through the critical range (approximately 1350 to 1600 deg F for most steels, depending on the composition), transformation to austenite takes place. The austenite grains are extremely small when first formed, but grow in size as the temperature above the critical range is increased, and, to a limited extent, as the time is increased. It is apparent, therefore, that both time and temperature must be constant in order to obtain reproducible results.

When temperatures are raised materially above the critical range, different steels show wide variations in grain size, depending on the chemical composition and the deoxidation practice used in making the heat. Heats are customarily deoxidized with aluminum, ferrosilicon, or a combination of deoxidizing elements. Steels using aluminum or other deoxidizers in carefully controlled amounts maintain a slow rate of grain growth at 1700 deg F, while heats finished with other deoxidizers, usually ferrosilicon, develop relatively large austenite grain size at temperatures somewhat below 1700 deg F.

The McQuaid-Ehn test is the one ordinarily used for determining grain size. Steel is rated with a set of eight ASTM charts that are compared one at a time with a specially prepared steel sample until one is found to match. Number 1 grain size, the coarsest, shows 1½ grains per sq in. of steel area examined at 100 diameters magnification. The finest chart is Number 8, which shows 96 or more grains per sq in. at the same magnification.

Properties Affected by Grain Size

Fine-grain steels (grain sizes 5, 6, 7, and 8) do not harden as deeply as coarse-grain steels, and they have less tendency to crack during heat-treatment. Fine-grain steels exhibit greater toughness and shock-resistance—properties that make them suitable for applications involving moving loads and high impact. Practically all alloy steels are produced with fine-grain structures.

Coarse-grain steels exhibit definite machining superiority. For this reason a few parts which are intricately machined are made to coarse-grain practice.

The correct specification and determination of grain structure in steel is a subject that has been given long study by Bethlehem metallurgists. If you would like suggestions on this or any other problem concerning alloy steels, these men will be glad to give you all possible help.

In addition to the entire range of AISI alloy steels, Bethlehem produces special-analysis steels and the full range of carbon grades.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

When you specify **Allis-Chalmers Induction Heaters—**

Expect the EXCEPTIONAL

The speed, convenience, cleanliness and economy of induction heating are spectacular in themselves. Yet Allis-Chalmers actually enhances those advantages with a practical approach to application.

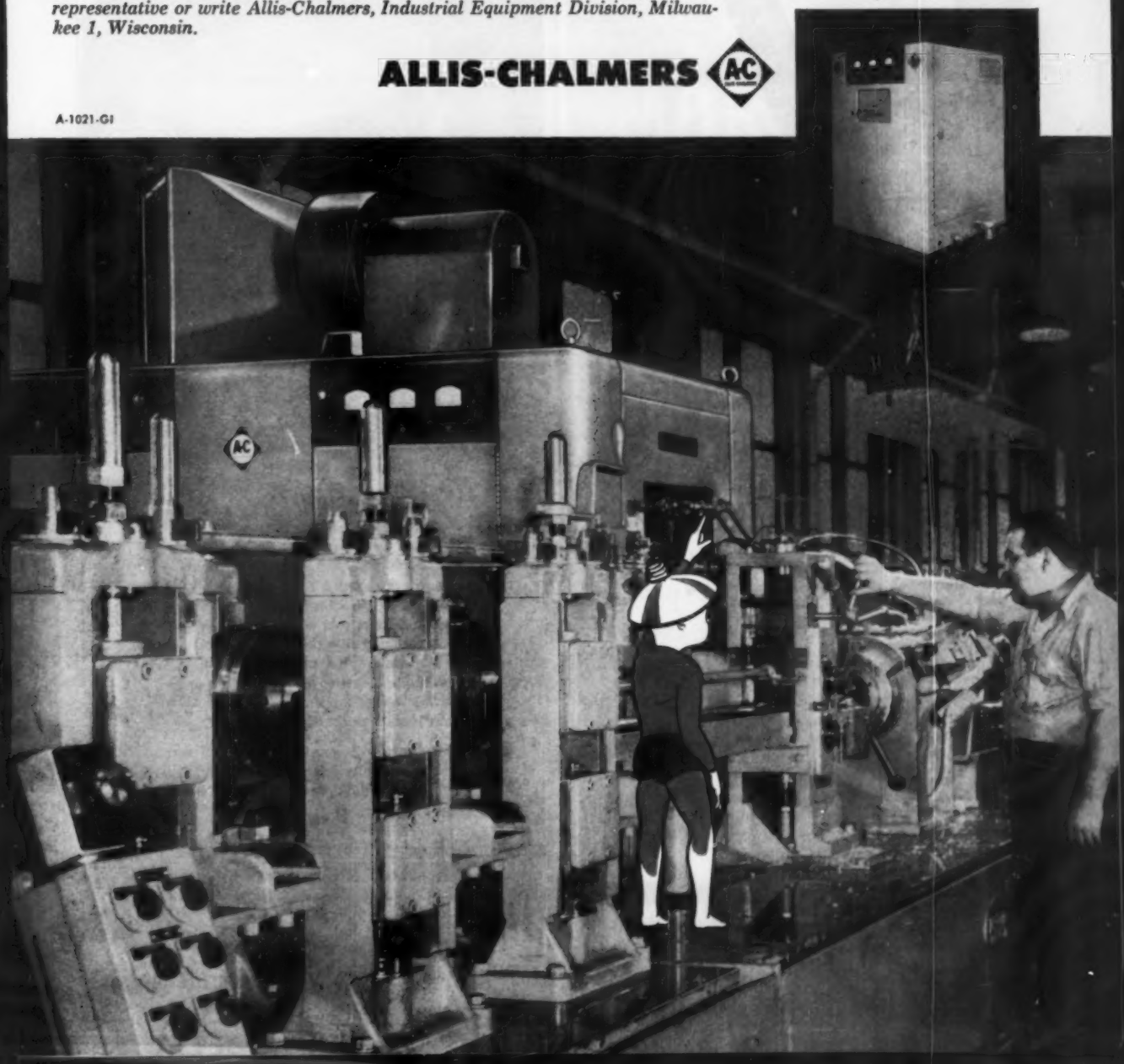
- **Test runs on your product** made in the A-C laboratory provide specific application data.
- **Special fixtures,** coils and work handling equipment designed and manufactured by A-C customize and streamline your operation.
- **Factory-supervised installation** gets your Allis-Chalmers induction heater off to a good start.
- **Periodic checkup and emergency maintenance service** supplied by regional offices keep your induction heater profitably productive — assure complete dependability.

If your job is one of brazing, soldering, hardening, annealing, or heating for forging, induction heating can do the job better, faster and at less cost. For double assurance of complete satisfaction, consider both the quality of the heater and the services of the manufacturer — insist on Allis-Chalmers. *See your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.*

Standout performance assured by EXTRA services

ALLIS-CHALMERS

A-1021-GI



NO CLEANING

NO PLATING

NO POLISHING

a Vital Detail not caught by the Camera's Eye

The camera caught clearly the action of this die operation . . . shows the blanking and forming operation, the dies, other details. What the lens has missed is the gleaming, durable plated finish of bright polished Chromium over a steel base. This operation is typical; indeed, mass fabrication of this finished raw material is familiar to most shop men today. Nickeloid Metals have proved they can retain their lustrous beauty, even when stamped, formed, blanked, bent, riveted, soldered or welded. For severe fabrication, Mar-Not protective coating can be supplied to protect the lustrous surface from scratching . . . quickly peeled off after fabrication. Write us for "Introductory Kit," including metal samples.

NICKELOID METALS SINCE 1898

American Nickeloid Company
Peru 2, Illinois
Plants: Peru, Ill. and Walnutport, Pa.

THE MARK OF QUALITY
BARBER COLMAN

Impressor

PORTABLE HARDNESS TESTER

- Rapid testing — no setup
- Easy to carry and use
- Needs only space for hand

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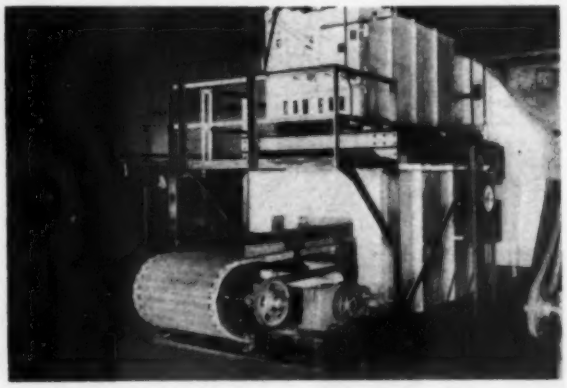

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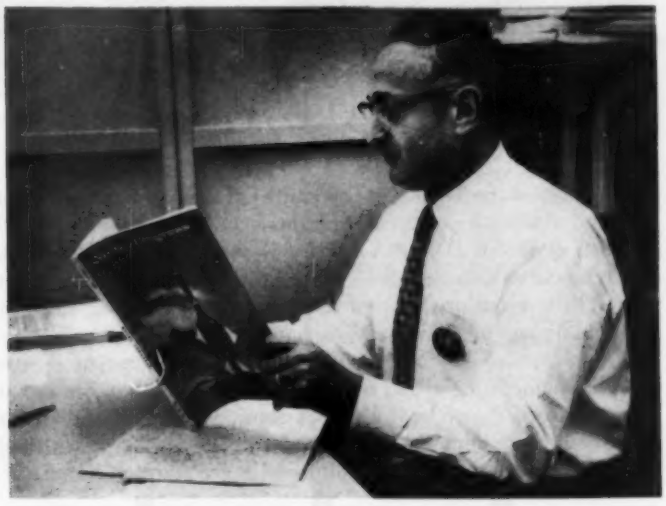
Behind the By-lines

Abraham Hurlich, author of the comprehensive article on metals and fabrication methods used for the Atlas (p. 65), joined Convair Astronautics three years ago following 15 years as chief of the materials engineering laboratory at Watertown Arsenal Laboratories. As supervisor of the materials research group responsible for the direction of materials research and development work, his present projects include a study of the behavior of materials at extremely low temperatures and ablation characteristics of materials at high temperatures. His workaday interests extend into his extracurricular activities—he is on the S.A.E. Committee on the Behavior of Steels



Abraham Hurlich Reads a Well-Known Metallurgical Journal

at Low Temperature and the Materials Advisory Board Panel of the Department of Defense Titanium Rolling Program.

Although Mr. Hurlich claims that his work is his main interest, he still finds time for hobbies—philately, anthropology and travel. Moreover, he is active in Boy Scout Troop work (he has three children) and, to fill in any spare moments, he is also writing a book on titanium.

T. E. Leontis is well qualified to report on magnesium in missiles and aircraft (see p. 82). Head of the operations and applications division of the metallurgical laboratory of Dow Metal Products Co., Midland, Mich., and also assistant to the director of the laboratory, his division is responsible for mechanical testing, development of new applications for magnesium (their role is to find applications for the unique properties of magnesium that are not being used), establishment of design criteria for magnesium and administration of the Laboratory's physical facilities. He came to Dow in 1944 and since then has concentrated on magnesium metallurgy.

His technical associations reflect his interest in magnesium. He

Behind the Bylines . . .

T. E. Leontis (Right) and J. W. Fredrickson Study Models of Missiles Many of Which Make Use of Magnesium

is a member of the Technical Committee of the Magnesium Association and chairman of the Melting and Casting Committee of the Institute of Metals Div. of A.I.M.E. Moreover, as a member of the Transactions Committee, he visits A.S.M. headquarters four times a year; he is a past president of the Saginaw Valley Chapter, and has held numerous offices in that chapter.

For relaxation, he turns to bridge (he has participated in many local tournaments), golf and reading the classics, both in English and modern Greek. (Since he is of Greek extraction, he is fluent in modern Greek but admits to finding ancient Greek a bit difficult.) His current special interest is the culture of the Byzantine Empire.

A. F. Hofstatter, author of the article on hot forming on p. 88, is shown below seated at a metallograph investigating a shop problem at Ryan Aeronautical Co. At present there are about 70 alloys in

use at Ryan for the manufacture of large airframe and engine components as well as rocket cases and various minimum weight structures. Al's interests lie chiefly in the heat treatment and forming of these alloys, and his most recent project is the fabrication of high pressure solid propellant rocket chambers. To fill in the spare moments, he is developing an impact test for foil gage materials to determine tear resistance.

Studying for a master's degree at night school uses up much of his spare time, but when he can, Al heads for the Pacific surf to wet his fishing line or the golf course for 18 holes.

Donald Flannery (right), who has been with Royal McBee Corp. for over 25 years (and is the author of the article on austempering typewriter bars on p. 91), started as an apprentice equipment engineer and worked up to his current job as chief equipment engineer. Now he is responsible for inplant tooling and power press operations and for checking out and recommending new equipment for plant production. His many years of experience have been supplemented by special courses in machine design at the University of Connecticut and Hillyer College. Most of his leisure time is spent actively engaged in community projects in Granby, Conn., where he is library director, member of the Town Charter Commission and Chairman of the Zoning Commission.

Robert C. Bates (below), who wrote the story on welding nodular cast iron on p. 95, joined Westinghouse Electric Corp. after his graduation from the University of Utah in June 1953 and has been there ever since. Until September 1955, he was concerned with

Behind the Bylines . . .

nonferrous applications and his principal responsibilities were nonferrous castings and copper-base wrought products. Since that time his main responsibilities have been ferrous castings, nonmagnetic alloys, stainless steels and high-temperature alloys.

One of his major interests is, naturally enough, the American Society for Metals and he has served on several committees for the Pittsburgh Chapter.

As nuclear metallurgist, J. H. Kittel and S. H. Paine are members of a new breed of engineers. These engineers must not only deal with the familiar effects of stress, temperature, fabrication and heat treatment, but also with the potent yet little understood effects that arise from neutron bombardment. Mr. Kittel and Mr. Paine's special area of study as nuclear metallurgists is the effects of irradiation (see their article on p. 119 where they discuss engineering decisions based on irradiation experiments). They were among the first to study the effects of irradiation on a variety of reactor materials, principally nuclear fuels, and their findings have been used to guide fuel specifications not only for reactors constructed by Argonne, but for many others. They find irradiation effects in metals a fascinating area of work and a never ending source of problems and surprises.

S. H. Paine (Left) and J. H. Kittel at Work in the Argonne National Laboratory

Mr. Kittel came to Argonne originally on loan from the National Advisory Committee for Aeronautics in 1947, then returned to NACA for a year, and in 1951 returned once more to Argonne to continue research on radiation effects on nuclear fuel. Since 1957 he has been group leader, engineering irradiation. Mr. Paine joined Argonne's metallurgy division in 1945 following eight years as general foreman of the heat treat division of Bell Aircraft Corp. and since 1946 has been a group leader, basic irradiation effects.

Covering an exhibition like the recent Soviet one in New York for *Metal Progress* (see p. 100) may have unexpected results. Arthur Tesmen, our Russian expert, not only discussed metalworking with E. P. Unksov, director of the Central Research Institute for Heavy Machine Building, but talked with well-known writer Velentin Katayev and painter Eugene Romas, not to mention the director of a cancer research institute and the vice-president of the geophysical year. According to Art, their highly "technical" conference covered such diverse topics as the respective qualities of American and Soviet wines, quaint customs of local waiters (seemingly a favorite topic, worldwide), and other such items of technical importance.

DEADLINE TOMORROW

They were blending calcium, dry zinc chloride, and dry thorium flouride. One of them noticed dust and gas escaping from an open mixer vent. He closed the vent and started the mixer. After a rumbling noise, a scorching burst of flame spewed for 40 feet. Two men dead. Six injured. Cause: undetermined.

This is but one result of the "unknown" factor in today's search for metals for nuclear reactors—metals for what must be understood as a vital technology.

The man who works with these metals is not too unlike any metals engineer in the industry. He is a lab technician, a physicist or a test engineer much like any other. But what makes his job extraordinary is fear. Not fear of "Cause: undertermined"; fear of too little progress and insufficient information in an area so vital to the national economy.

The American Society for Metals has published a new volume which will introduce to you this struggle for progress and understanding in the development of metals for nuclear reactors . . . that's the title, "Metals for Nuclear Reactors". It talks about zirconium, thorium, uranium, cadmium—nuclear metals. The words toxic and pyrophoric are common.

W. A. Maxwell, technical editor of "Metals for Nuclear Reactors", describes the tone of this book in Chapter 2, which he personally wrote: "In view of the limited material situation, much present designing is done in desperation. The reason for this is quite simple. To build a reactor at all, available materials must be utilized. Available materials, however, are often barely adequate for reactor environments; improving these materials offers a challenging future . . ."

Do not mistake this book as a text for metals engineers in the nuclear field only. It should be read by any man associated with the myriad of metals problems in today's era of unprecedented progress. A large number of problems common to other metals interests are intensified in the reactor field. Corrosion difficulties are certainly encountered in every aspect of materials work, but reactor corrosion claims some of the most rigorous conditions and tightest specifications. As another example, the development of high temperature alloys for jet engine turbine blades was one of the most important developments of recent years, and while similar alloys are badly needed for reactors, the metals engineer will have to do his work with a different and unpromising set of elements. You will be introduced to the use of exotic materials which only days ago were textbook curiosities.

"Metals for Nuclear Reactors" is an introduction to an imminently brilliant technology . . . an accounting of where we are today in the development of nuclear power . . . a documentation of how well we are combating the austere, uncompromising fact that as the demand for electrical power is going up, the supply of coal and oil is going down. Don't miss reading it. You will know just where we stand and what we have yet to do.

Core of a homogeneous research reactor built by Atomics International for Armour Research Foundation. Sphere contains a solution of uranium salts and is cooled by the coil. Photo reprinted from ASM's new book, "Metals for Nuclear Reactors".

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STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

Required by the Act of Congress of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) showing the ownership, management and circulation of **Metal Progress**, published monthly at Mount Morris, Illinois, for October 1, 1959.

1. The names and addresses of the publisher, editor, managing editor and business managers are: Publisher, American Society for Metals, Metals Park, Novelty, Ohio; Editor, Allen G. Gray, Metals Park, Novelty, Ohio; Managing Editor, Marjorie R. Hyslop, Metals Park, Novelty, Ohio; Business Manager, Allan Ray Putnam, Metals Park, Novelty, Ohio.

2. The owner is: (if owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual member, must be given.) The American Society for Metals, Metals Park, Novelty, Ohio, which is an educational institution, the officers being: President, C. H. Lorig; Vice President, Walter Crafts; Secretary, W. E. Jominy; Treasurer, R. H. Aborn; Trustees: John H. Hollomon, E. E. Stansbury, Earl Parker, M. A. Scheil and G. M. Young.

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5. The average number of copies of each issue of this publication sold or distributed, through the mails, or otherwise, to paid subscribers during the 12 months preceding the date shown above was: (This information is required from daily, weekly, semi-weekly and tri-weekly newspapers only).

Allen G. Gray
Editor

(Seal)

Sworn to and subscribed before me this 28th day of September, 1959.

David E. Clarke
Notary Public

(My commission expires September 7, 1960.)

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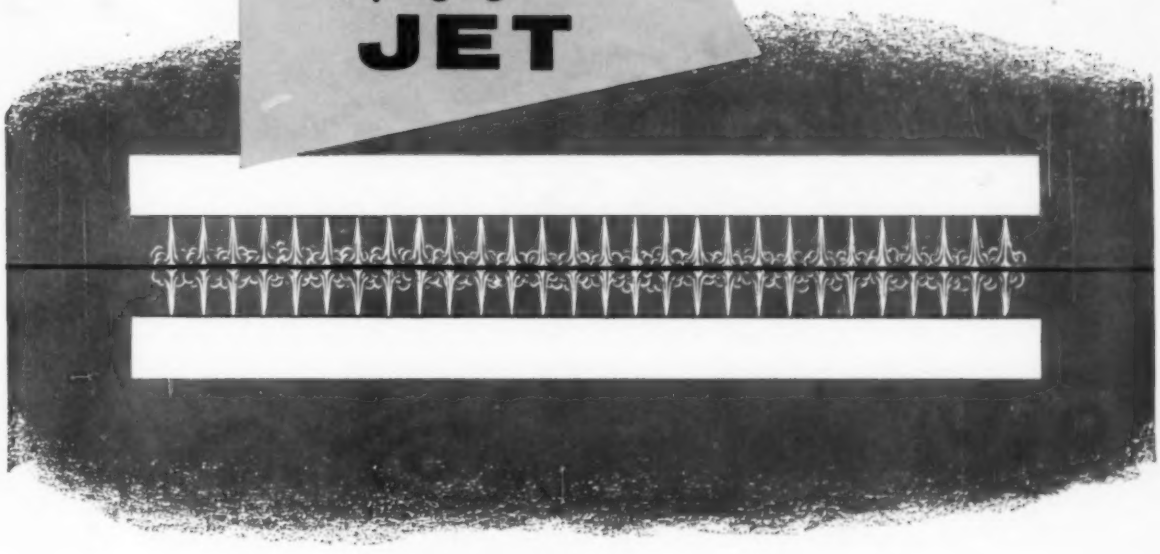

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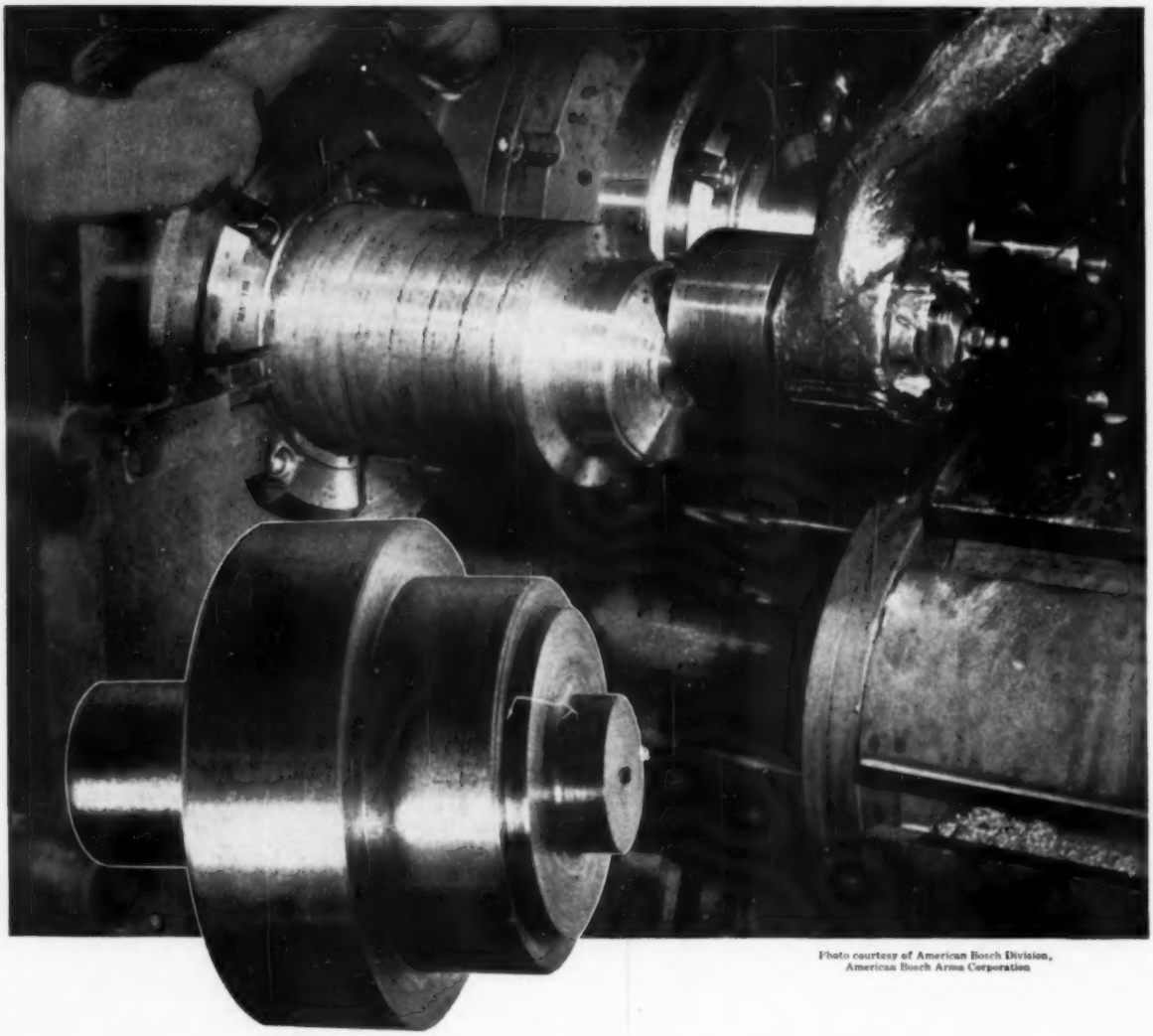

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